Urban Residential Energy Efficiency - Technology Optimization and Behaviour Change:
Case study on social housing in Darmstadt, Germany

vom Fachbereich Bau- und Umweltingenieurwissenschaften
der Technischen Universität Darmstadt

Zur Erlangung des akademischen Grades
Doktor-Ingenieur
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von Jie Zheng

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Vorwort des Doktorvaters

Mit dem Mitteilungsheft Nr. 109 publizieren das Institut und die Versuchsanstalt für Geotechnik der Technischen Universität Darmstadt die wissenschaftliche Forschungsarbeit von Frau Dr.-Ing. Jie Zheng, die die Energieeffizienz von städtischem Wohnungsgebäuden behandelt. Die vorliegende Forschungsarbeit führt die wissenschaftlichen Analysen um Energieeffizienz von Gebäude fort, die durch ausführliche Analyse der technischen Integration und des Einfluss von energetischem Nutzerverhalten für eine behagliche ökologische Qualität des Innenraums erreicht. Der Energieverbrauch von Wohngebäuden variiert mit physischen Unterschieden zwischen der Größe von Wohnungen, Arten der Grundstücken, Alter von Wohngebäuden und Leistungsgrad der Energiesystem, die Klima und Energiepreise, sowie auch Nutzerverhalten und Bewusstsein für Energieeinsparung im Besonderen, das von einzelnem sozioökonomischen Hintergrund betroffen sind. Außer bau- und energietechnische Faktoren von Gebäuden ist die Analyse energetisches Nutzerverhaltenes ein andere Schwerpunkt dieser Forschungsarbeit. Die Nutzerinteraktion bezüglich Energieeffizienz im Wohngebäude wird immer wichtiger in der Kontrolle der umweltfreundlichen Innenraum Qualität und Energieverbrauch. Aus diesem Grund kommt den Analysen des subjektiven Einflussfaktors für eine nachhaltige Optimierung der Energieeffizienz von Wohngebäuden daher große Bedeutung zu.

Frau Dr. Zheng hat in ihrer wissenschaftlichen Forschungsarbeit den Gründe, Herausforderungen und Optimierungsmöglichkeiten ausführlich analysiert und den Einflussfaktoren unter Deutschland, China und USA detailliert verglichen. Ein neues methodisches Konzept wird noch von ihr entwickelt, das ansonsten das energetische Nutzerverhalten während der Analysieren und Simulieren in Betracht zieht, um das Energieeinsparungspotenzial der Interaktion zwischen Nutzern und Energiesystem im Gebäude zu erkunden.

Das Ergebnis der umfangreichen, wissenschaftlichen Forschungen von Frau Dr. Zheng ermöglicht es, die Analyse von Gebäude-Energieeffizienz auf holistische Weise im Hinblick auf die Bautechnik, Energieversorgungstechnik, energetische Nutzerverhalten und energieeinsparende Bewusstsein, sowie Energiepolitik und -wirtschaft zu erreichen.

Darmstadt im August 2019

Rolf Katzenbach

Vorwort der Autorin

Die gegenständliche Arbeit entstand im Rahmen meiner wissenschaftlichen Forschungsarbeit bei Herrn Professor Katzenbach am Institut und der Versuchsanstalt für Geotechnik der Technischen Universität Darmstadt.

Das Erfordernis zu meiner Forschungstätigkeit ergab sich aus Fragestellungen zur Energieeffizienz von städtischem Wohngebäuden bezüglich energetischer Optimierungen und Nutzerverhaltensänderungen. Diese Forschungsarbeit wurde als ein interdisziplinäres Thema entwickelt, das die objektiven Einflussfaktoren, z.B. Gebäudetechnik und Versorgungstechnik (TGA), und den subjektiven Einflussfaktoren, z.B. ökonomischer und -demographischer Status von Bewohnern angeht.

Über die Entstehung dieser Arbeit haben mich viele Menschen begleitet, denen ich an dieser Stelle aufrichtig danken möchte. Der erste Dank gilt meinem verehrten Doktorvater Herrn Prof. Dr.-Ing. Rolf Katzenbach. Professor Katzenbach hat mich nicht nur bei meinem Promotionsvorhaben herausragend betreut. In den vergangenen Jahren habe ich als Mitarbeiterin an seinem Lehrstuhl fachlich und persönlich sehr viel von ihm lernen dürfen. Ebenso danke ich Herrn Schneider, der sich freundlicherweise als Korreferent zur Verfügung gestellt hat. Bei Frau Professorin Dipl.-Ing. M. Arch. Anett-Maud Joppien bedanke ich mich auch, die mir vielen Möglichkeiten und Chancen geboten hat, mit der ich meine Forschungsarbeit in architektonischer Hinsicht eingehend und umfassend erforschen dürfe. Herrn Professor Zachert möchte ich an dieser Stelle für das ehrlich Interesse an meiner Arbeit und den Diskussionen über das Thema danken. Vielen Dank an meine Kollegen in meinem Institut und an andere Doktoranden in der Graduiertenschule für Energiewissenschaft und Energietechnik. Ich möchte auch Dr. Tianzhen Hong und Dr. Sang Hoon Lee meinen Dank aussprechen, die mir viele Unterstützungen für meine Forschungsarbeit während meines Forschungsaustauschs im Lawrence Berkeley National Laboratory, USA gegeben haben, und sowie Vorschläge an meiner Dissertation sogar nach dem Austauschprogramm weiter bieten. Ich möchte mich noch bei der Darmstädter Exzellenz-Graduiertenschule ESE und der Deutschen Forschungsgemeinschaft (DFG) bedanken, die mir die Möglichkeit gegeben hat, meine Forschungsarbeit und Erfahrungen auf dem fachlichen Gebiet auszuweiten und mich finanziell zu unterstützen.

Von ganzem Herzen möchte ich mich bei meinen Eltern, Xiaolan, Sun und Bingzhao, Zheng, bedanken. Sie haben mir mit ihrer Liebe und Wertschätzung den nötigen Rückhalt für dieses Vorhaben gegeben. Selbstverständlich gibt es auch vielen Dank von mir an meine Freunde in China und Deutschland, die ihren Zuspruch und Liebe im wesentlichen Maße zum Gelingen der Arbeit beigetragen haben.

Darmstadt, im August 2019
Jie Zheng

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This dissertation was carried out within a doctoral research work in the Graduate School Energy Science and Engineering at Technische Universität Darmstadt. It is a part of the interdisciplinary subject involving technical and socio-economic aspects.

Not only the completion of this thesis, but also my long journey of Ph.D. work could not be achieved successfully without a full support from my supervisors, Professor Dr.-Ing. Rolf Katzenbach and Professor Dipl.-Ing. M. Arch. Anett-Maud Joppien. Likewise, many thanks for the support from Professor Jens Schneider, who has kindly made available as the co-referent for my dissertation. Your valuable guidance, advices and contribution to my research are highly appreciated and gratefully acknowledged.

Many thanks to my colleagues in my institute (Institut und Versuchsanstalt für Geotechnik) and other Ph.D. fellows in Graduate School ESE for your kind help and valuable opinions. I would also like to express my deepest gratitude to Dr. Tianzhen Hong and Dr. Sang Hoon Lee for their strong support and constructive advices on my research work during my Research Exchange in Lawrence Berkeley National Laboratory (LBNL), the U.S., and continual suggestion on my thesis work even I finished my exchange program and left LBNL.

I would like to express my gratitude to the Graduate School ESE, TU Darmstadt and DFG (Deutsche Forschungsgemeinschaft) which gave me the opportunity to extend my research work and experience in the field of energy efficiency research and provided me the financial support for my research.

Deeply from my heart with love and faith, I would like to thank my beloved parents, Xiaolan Sun and Bingzhao Zheng. They taught and are teaching me the highly valuable experiences and lessons of lifetime, gave me unconditional support, encouragement during my Ph.D. work and throughout my life. There are also many thanks to my friends I care to name.

Darmstadt, in August 2019
Jie Zheng

Dedicated to

my lovely mother and father

This humble work is a sign of my love to you!

献给我最爱的爸爸妈妈

“You cannot teach a person something he does not already know; you can only bring what he does know to his awareness”

----by Galileo Galilei

“Ich kann freilich nicht sagen, ob es besser wird, wenn es anders wird; aber so viel kann ich sagen, es muss anders werden, wenn es gut werden soll.”

----by Georg Christoph Lichtenberg

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Abstract

Energy efficiency has been the core challenge and task of research in the building sector and strongly driven by real estate, resource management, energy policy and consumers with various socio-economic backgrounds. In Germany, the average share of final energy for residential sector accounted for 26% of total final energy consumption (BMWi, 2017), which was almost double than the worldwide average level with 12.6% (EIA, 2017).

Existing building energy analysing tools have achieved a high dynamic dimension of energy consumption through accurate analysis of the technical integration of building energy system. However, the impact of occupant interactions with the control of indoor environmental quality on building energy performance is underestimated. Residential energy consumption varies with physical differences in the size of dwellings, type of properties, age of residential buildings and efficiency of domestic electrical appliances and energy equipment, climate and energy prices, as well as occupant behaviour, in particular, which are affected by individual socio-economic background. A balance between reducing energy bills and without sacrifices of living comfort is pursued by all stakeholders related to residential energy use. Though building energy-saving technologies, low-energy building concepts and building energy management system have reached to a mature degree, a gap between the designed and real residential energy consumption appears often.

This research work considered occupant behaviour as an important influencing factor in controlling indoor environmental quality and energy consumption. A case study on energy consumption of German social housing was discussed. The process of collecting occupant behaviour data and the technological support were introduced, which were based on projects about social housing energy efficiency and those data works as basic input for further simulation process. A new concept was proposed through integrating occupant behaviour into the conventional Retro-commissioning methodology, so as to explore the energy conservation potential of the interaction between occupant behaviour and building energy system.

IDA ICE as the modelling tool in this work was simulating the energy consumption of the total building, and the individual energy consumption and indoor air quality of each dwelling, as well as the living comfort indices respectively. A series of comparison on those simulation results among different dwellings with different occupancy rate and using schedules of energy-related appliances as well as other potential influencing factors were presented to prove the synergic effect of objective (technics) and subjective (occupants) impacts on home energy consumption and indoor environmental quality.

Zusammenfassung

Als zentrale Herausforderung und Aufgabe der Forschung im Bausektor wird die Energieeffizienz stark von Immobilien, Ressourcenmanagement, Energiepolitik und Verbrauchern mit verschiedenen sozioökonomischen Hintergründen angetrieben. In Deutschland entfielen 26% des Endenergieverbrauchs auf den gesamten Endenergieverbrauch (BMWi, 2017), der fast doppelt so hoch wie der weltweite Durchschnitt mit 12,6% (EIA, 2017) war.

Vorhandene Verfahren um Energieeffizienz von Gebäude zu analysieren haben eine hohe dynamische Dimension des Energieverbrauchs durch ausführliche Analyse der technischen Integration der Gebäude-Energiesysteme erreicht. Der Einfluss von Nutzerverhalten oder -Interaktion durch die Kontrolle der ökologischen Qualität des Innenraums auf die Energieeffizienz von Gebäuden wird jedoch unterschätzt.

Der Energieverbrauch von Wohngebäuden variiert mit physischen Unterschieden zwischen der Größe von Wohnungen, Arten der Grundstücken, Alter von Wohngebäuden und Leistungsgrad der Energiesystem, die Klima und Energiepreise, sowie auch Nutzerverhalten und Bewusstsein für Energieeinsparung im Besonderen, das von einzelnem sozioökonomischen Hintergrund betroffen sind. Einem Gleichgewicht dazwischen, Energierechnungen zu reduzieren und ohne Ofer des Lebenskomfort wird von allen Stakeholdern angestrebt. Obwohl energiesparende Technologien, Niedrigenergie-Gebäudekonzepte und Energiemanagementsysteme von Gebäuden einen ausgereiften Grad erreicht haben, scheint oft eine Kluft zwischen dem geplanten und dem tatsächlichen Energieverbrauch der Wohngebäude zu bestehen.

Nutzerverhalten wird in diese Arbeit als ein wichtiger Einflussfaktor in der Kontrolle der umweltfreundlichen Innenraumqualität und Energieverbrauch. Erhebung von Daten der energetischen Nutzerverhaltene und technischen Ausrüstungen in das untersuchten Gebäude wurden umgesetzt durch unterschiedene Verfahren, z.B., Umfrage mit Fragebogen, Vor-Ort-Inspektion, und Analyse und Kalkulation usw., damit konnten als Grunddaten für weitere Simulation der Fallstudie genutzt werden. Ausgehend von der konventionellen Methodik „Retro-Commissioning „ wird ein neues methodisches Konzept diskutiert, das ansonsten das energetische Nutzerverhalten während der Analysieren und Simulieren in Betracht zieht, um das Energieeinsparungspotenzial der Interaktion zwischen Nutzern (Bewohnern) und Gebäudesystem zu erkunden.

IDA ICE als eine Modellierungssoftware simuliert in dieser Arbeit den Energieverbrauch des gesamten Gebäudes und den individuellen Energiekonsum und die Raumluftqualität, sowie die Wohnkomfort. Analyse und Vergleich auf der Ergebnisse der Simulation zwischen verschiedenen Wohnungen werden gezeigt, die mit unterschiedlicher Belegungsrate und individueller Verhalten (z.B. tägliche Nutzungspläne von elektrischen Haus-

haltsgeräten) vorgestellt werden, um den synergetischen Effekt von objektive (Technologie) und subjektive (Bewohner) Auswirkungen auf den Energieverbrauch und die ökologischen Qualität von Innenraum zu belegen.

List of acronyms and symbols

Acronyms

AB	Annual benefits
ABC Model	Attitude-Behaviour-external Conditions Model
AC	Annual costs
A/C	Air conditioning
ACEEE	American Coucil for an Energy Efficient Economy
ACH	Air Change per Hour
ACR	Air Change Rate
AGEB	Arbeitsgemeinschaft Energiebilanzen
AQSIQ	The General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.
BAFA	Bundesamt für Wirtschaft und Ausfuhrkontrolle
BauGB	Baugesetzbuch
BBSR	Bundesinstitut für Bau-, Stadt- und Raumforschung
BDEW	Bundesverband der Energie- und Wasserwirtschaft e. V.
BECP	The U.S. Department of Energy Building Energy Codes Program
BER	Building Energy Rating
BEST	Building Energy Simulation Tool
BMS	Building Management System
BMVIT	Bundesministium für Verkehr, Innovation und Technologie, Austria
BMWi	Bundesministerium für Wirtschaft und Energie
BTO	The American Building Technologies Office
Btu	British thermal units
CAV	Constant Air Volume systems
CBA	Cost-Benefit-Analysis
CCA	Cost-Comfort-Analysis
CDD	Cooling Degree Days
CDIAC	Carbon Dioxide Information Analysis Center
CEA	Cost-Effectiveness-Analysis
CEL	China Energy Label
CFLs	Compact Fluorescent Bulbs
cfm	Cubic Feet per Minute (Unit of ventilation rate), 1 cfm (ft^3/min) = 1.7 m^3/h = 0.47 l/s
CIE	Commission Internationale de l'éclairage (english: International Commission on Illumination; deutsch : Internationale Beleuchtungskommission)
CLA	Consumer Lifestyle Approach

COP	Coefficient of Performance
dena	Deutsche Energie-Agentur GmbH
DeStatis	Das Statistische Bundesamt
DHW	Domestic Hot Water
DNAS	Drivers-Needs-Actions-Systems
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen
DIN	Deutsches Institut für Normierung e.V.
DOE	Department of Energy, U.S.
DWD	Deutscher Wetterdienst
EBC	Energy in Buildings and Community
EBCx	Existing Building Commissioning
EC	European Commission
EDGAR	Emissions Database for Global Atmospheric Research
EEA	European Economic Area
EED	Energy Efficiency Directive
EEM	Energy Efficiency Measure
EEWärmeG	Erneuerbare-Energien-Wärmegesetz
EFH	Einfamilienhaus
EIA	Independent Statistics & Analysis U.S. Energy Information Administration
EJ	Exajoule
EMCS	Energy Management Control System
EM&V	Evaluation, Measurement and Verification Protocol
EN	European norm
EnEG	Energieeinsparungsgesetz
EnEV	Energieeinsparverordnung
EnVKG	Energieverbrauchskennzeichnungsgesetz
EnVKV	Energieverbrauchskennzeichnungsverordnung
EPA	U.S. Environmental Protection Agency
EPA-ED	Energy Performance Assessment of Existing Dwellings
EPBD	Energy Performance of Buildings Directive
EPBD-CA	Directive on the Energy Performance of Buildings-Concerted Action
EPC	Energy Performance Contracting
EPCs	Energy Performance Certificates
EPS	Expanded Polystyrene
ESCO	Energy Service Company
ESM	Energy Saving Measures
EU	European Union
FHA	The U.S. Federal Housing Administration
FHKV	Funkheizkostenverteiler
GdW	Bundesverband deutscher Wohnungs- und Immobilienunternehmen

GEMIS	Globale Emissions-Modell integrierter System
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GmbH	Gesellschaft mit beschränkter Haftung
GMH	Großes Mehrfamilienhaus
GSHP	Ground Source Heat Pump
GUI	Graphical User Interface
HDD	Heating Degree Days
HeizAnlV	Heizungsanlagen-Verordnung
HERS	Home Energy Rating System
HPF	Housing Provident Fund (in China)
HSPF	Heating Seasonal Performance Factor
HVAC	Heating, Ventilation and Air Conditioning
ICC	International Code Council
ICT	Information and Communication Technology
IEA	International Energy Agency
IEA-ETSAP	International Energy Agency-Energy Technology Systems Analysis Program
IECC	International Energy Conservation Code
IINAS	Internationales Institut für Nachhaltigkeitsanalysen und -Strategien
IPMVP	International Performance Measurement and Verification Protocol
IRc	Integrated Retro-commissioning
IRC	The U.S. Internal Revenue Code
IRS	Internal Revenue Service
ISO	The International Organization for Standardization
IWEC	International Weather for Energy Calculations
KF	Klimafaktor
KfW	Kreditanstalt für Wiederaufbau
kWh, TWh	Kilowatt hour, Terawatt hour
LBNL	Lawrence Berkeley National Laboratory
LCA	Life-Cycle Assessment
LCE	Life-Cycle-Energy
LDC	Load Duration Curve
LEED	Leadership in Energy and Environmental Design
LfU	Bayerisches Landesamt für Umwelt
LIHTC	The Low-Income Housing Tax Credit of United States
LWR	Length-Width-Ratio
MBtu	million British thermal units
MC	Marginal cost
MC-PRC	Ministry of Construction of the People's Republic of China
MET	Metabolic Equivalent
MFR	Multi-Family Residence

MHNT	Maslow's Hierarchy of Needs Theory
MOC	The Ministry of Construction of the People's Republic of China
MOHURD	The Ministry of Housing and Urban-Rural Development of the People's Republic of China
Mtoe	Million tonnes of oil equivalent
MWh	Megawatt hour
NBSC	National Bureau of Statistics of China
NDRC	National Development and Reform Commission of the People's Republic of China
NIR	Nationaler Inventarbericht zum deutschen Treibhausgasinventar
NPV	Net Present Value
OB	Occupant Behaviour
ODEX	Measurement Index of Energy Efficiency
OECD	Organization for Economic Co-operation and Development
OPR	Owner's project requirements
OSHA	Occupantional Safety and Health Administration
PEF	Primary Energy Factor
PMV	Predicted Mean Vote
PPD	Predicted Percentage of dissatisfied
ppm	Parts per million (unit of level of CO_2), 1 ppm = 10^{-6} = 0.0001%
PRC	The People's Republic of China
PTEM	Physical-Technical-Economic Model
PV	Photovoltaic
PV	Present value
QOL	Quality of Life
Quad	Quadrillion Btu
RCIB	Residential Customer Information and Behavior
RCx	Retro-commissioning
RE	Rebound Effect
RF	Radio Frequency
RH	Relative humidity
ROI	Return on Investment
RWI Essen	RWI - Leibniz-Institut für Wirtschaftsforschung
SCE	standard coal equivalent
SEER	Seasonal Energy Efficiency Ratio
SFR	Single-family residence
SHGC	Solar Heat Gain Coefficient
SRI	Solar Reflectance Index
STES	Seasonal Thermal Energy Storage
STIRPAT	Stochastic Impacts by Regression on Population, Affluence and Technology
STS	Solar Thermal Systems
TC	Total cost

TPB	Theory of Planned Behavior
TRY	Testreferenzjahre, Unit in KF = G(TRY, P)/G
TRV	Thermal Radiator Valves
TWh	Terawatt hours
UNEP	United Nations Environment Programme
VAT	Value-Added Tax
VAV	Variable Air Volume systems
VBN Theory	Value-Belief-Norm Theory
VDE	Verband der Elektrotechnik, Elektronik und Informationstechnik
VT	Visible Transmittance
WoBindG	WohnungsbindungsGesetz
WSVO 95	Wärmeschutzverordnung 95
WWR	Window-to-wall ratio
WDVS	Fachverband Wärmedämm-Verbundsysteme e. V.
XPS	Extruded polystyrene
ZSE	Zentrales System Emissionen

Symbols

A_i	area of the envelope component i of building	$[m^2]$
A_N	effective energy-related floor area	$[m^2]$
b^k	benefits of category k	[-]
c^k	costs of category k	[-]
c	specific heat capacity	$[J/(kg \cdot K)]$
d	thickness of building component	[m]
g	energy transmittance value	[-]
h_g	ceiling height	[m]
H_D	the transmission heat losses	[W/K]
H_T	transmission heat loss	[W/K]
H'_T	specific transmission heat loss	$[W/(m^2 \cdot K)]$
H_V	specific heat loss of ventilation	[W/K]
l_k	length of the linear thermal bridge k	[m]
q	air supply into a zone	$[m^3/h, ft^3/h]$
Q	total annual heat demand of building	[kWh/a]
Q_h	annual heating energy demand of building	[kWh/a]
Q_i	internal heat gains	[kWh/a]
Q_P	annual primary energy demand	[kWh/a]
Q_S	solar heat gains	[kWh/a]
Q_r	energy input from regenerative sources to heating system	[kWh/a]
Q_t	heat loss of energy-related equipment for heating and DHW	[kWh/a]
Q_W	annual heat demand for water heating	[kWh/a]
R	thermal insulation resistance	$[m^2 \cdot K/W]$
Rsi	thermal insulation resistance of inner building component	$[m^2 \cdot K/W]$
Rse	thermal insulation resistance of external building component	$[m^2 \cdot K/W]$
t	time	[h]
U_i	thermal transmittance coefficient of building components i	$[W/(m^2 \cdot K)]$
V	zone volume	$[m^3]$
V_{air}	air volume	$[m^3]$
V_e	heated building volume	$[m^3]$
δ_i	efficiency factor of energy equipment and appliances i	[-]
ζ_i	energy-related behavioural elements of occupants I	[-]
η_i	thermal characteristics of building components, a weighted value	[-]
λ	thermal conductivity coefficient	$[W/(m \cdot K)]$
ψ_k	thermal transmission coefficient of the linear thermal bridge k	$[W/(m \cdot K)]$
χ_j	thermal transmittance of the point thermal bridge j	[W/K]

1 Introduction

Energy consumption in the residential sector includes all energy consumed by households, excluding transportation uses. (International Energy Outlook 2016). It consists of energy used for space heating and cooling, domestic hot water (DHW), lighting, ventilation, household electrical appliances and digital products, such as mobile phone and tablet. Residential energy consumption is determined by various external and internal factors, which refer to climate and environmental condition, availability of energy sources and the corresponding energy prices, and housing policies, as far as the society as a whole. While in the individual, it refers to socio-economic background of households, the location of the residential units, the efficiency of energy equipment and domestic electrical appliances, and the attitude and behavior of occupants towards energy using, as well as the availability of access to energy conservation information.

With the rapid economic development and increasing information and communication technology (ICT), the energy allocation has changed significantly from the main part for infrastructure and industry decades ago to more energy and resource consumption on domestic sector, particularly for human habitable space that is gradually evolved into an integrated space for living, working and entertainment instead of only a shelter from wind and rain. This allocation change raises sustainability issues due to limited resource and some unreasonable energy distribution. In last decades, many studies on building structures and energy-related equipment as well as domestic electrical appliances have undertaken to relieve high residential energy expenditure limited by technological deficiencies, but still a relatively little scientific research to analyze energy-related occupant behaviour and relevant energy management in the residential sector.

Energy consumption in the life span of buildings happens during the main five activities (UNEP 2009):

- Fabricating or manufacturing energy: production and manufacture of building materials,

- Grey energy: transport of building materials from production plants to building sites,

- Induced energy: construction of the building,

- Operational energy: operation of the building,

- Energy for recycling: demolition of buildings and reuse of their parts, where this occurs.

The majority of existing studies on residential energy efficiency with Life-Cycle-Analysis

(LCA) method indicate that buildings' required energy in the lifespan is mostly represented by operational energy, which is consumed during the building occupying period from commission to demolition (Haynes 2013, p.3) to meet occupants‘ energy demand for living and indoor activities. This share of energy ranges from three quarters to 95% of the total life cycle energy (LCE) and mainly is distributed for ensuring the indoor thermal comfort of households. Therefore, how to optimize the residential building energy efficiency during the operational phase is becoming a critical research direction. This challenge appears not only in developing countries where to confront housing shortage and relatively low building energy efficiency but also in the developed countries where a sound residential energy supply and utilization system has been well formed generally. Developing countries are eager to find an efficient and sustainable way to solve the problems of energy shortage and environmental threat under the pressure of a continuous urbanization. Meanwhile, most of existing residential buildings in developed countries are suffering the underserved and low-efficient operation models, in particular, some European countries where the insulation system and energy facilities in the existing residential buildings need energy-related refurbishment and modernization urgently.

This chapter establishes the research context of energy efficiency in residential buildings with a problem statement, thereby explaining the research motive, deriving the research focus and expected research objects. A brief analysis of energy consumption provides the view of the state of energy demand and supply in the residential sector compared with other industrial sectors, as well exploiting the possible influencing factors.

1.1 Research context and problem statement

Residential building sector is the most intractable part in tackling matters of building energy efficiency because the operation of residential buildings is affected or controlled by more complexes and random factors than those in commercial or public buildings, particularly the diverse energy using behaviour of occupants. In addition, other influencing factors should be not overlooked too, when considering the building energy performance, such as year of construction, building standards or laws on energy conservation and the relevant building energy efficiency policies, which have large disparities in different countries. For example, more than half of residential buildings in Germany were built until 1969 (DeStatis 2014) before the first Law on Energy Saving in Buildings, i.e. the German Energy Saving Act[1] (EnEG) came into force in 1976. Meanwhile, only about

[1] The German Energy Saving Act, in Germa: Energieeinsparungsgestz, EnEG or Gesetz zur Einsparung von Energie in Gebäuden.

10%[2] were built between 2000 and 2011 complying with the EnEG and the German Energy Saving Ordinance[3] (EnEV). In China, building stock is characterized by rapid new construction and demolition of older buildings, mostly owing to a large-scale urban expansion (Amecke et al. 2013). Accordingly, high building standards and increasingly improved efficiency of energy equipment are becoming one of critical challenges for its sustainability. In the United States, a high share of building energy is consumed for the operation of energy facilities and devices, and besides, energy saving in buildings is challenged by the relatively low energy prices and overdesigned living areas and appliances. According to statistics by the U.S. Energy Information Administration (EIA 2017), the delivered energy consumption accounted 54.5 quadrillion Btu (or 1.594E+04 TWh) in residential buildings, much more than that in commercial buildings with 30.3 quadrillion Btu (or 8.88E+03 TWh). Fig. 1.1 illustrates the delivered energy consumption by the main four end-use sectors in 2015.

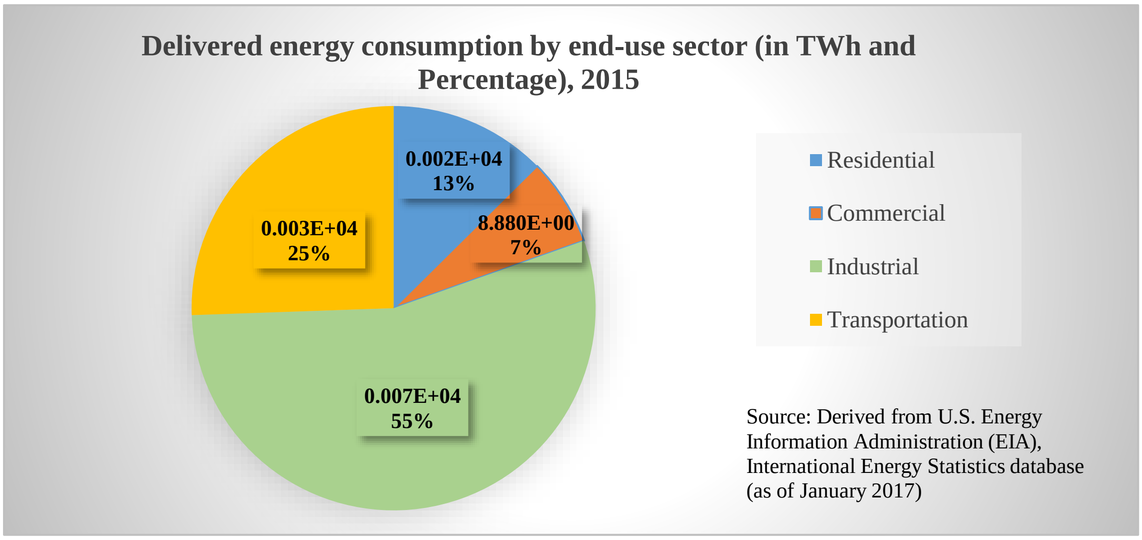

Figure 1.1 The delivered energy consumption by end-use sector, worldwide

Besides, energy consumption in different end-use sectors indicates a continuous upward trend based on the prediction by EIA, e.g., residential energy consumption would rise to 79.3 quadrillion Btu (2.324E+04 TWh) until 2050, about increasing 46 per cent in comparison with 2015, as Fig. 1.2 shown below.

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2 http://www.statistik-portal.de/Statistik-Portal/de_jb08_z5.asp

3 Energieeinsparverordnung: EnEV identifies minimum requirements regarding energy use of new built and renovated buildings (e.g., residential, commercial and public).The first version of EnEV came into force since 1st February 2002.

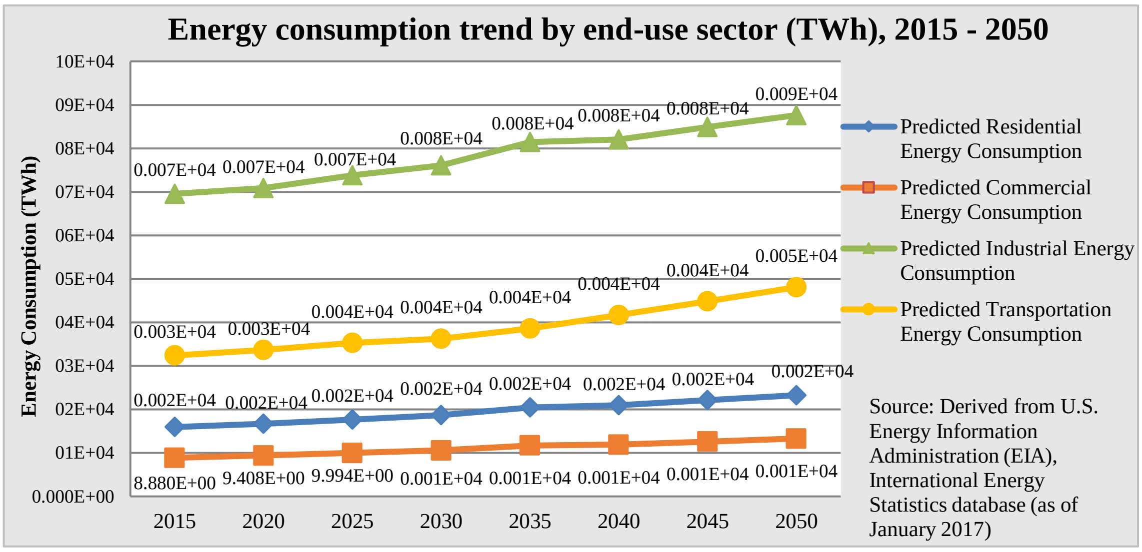

Figure 1.2 Energy consumption trend by end-use sector 2015-2050, worldwide

In EU-28 the share of end-energy consumption in residential building accounted 25.4 per cent of the total end energy consumption in 2015[4]. It was much higher than the average ratio worldwide, even a slow fall of average household energy consumption per dwelling has occurred since 2000 with a regular decrease -1.3 per cent per year. However, Germany accounted a slight higher (25.8 per cent) than the average ratio of EU-28. Fig. 1.3 illustrates the energy consumption by end-use sector in Germany 2015.

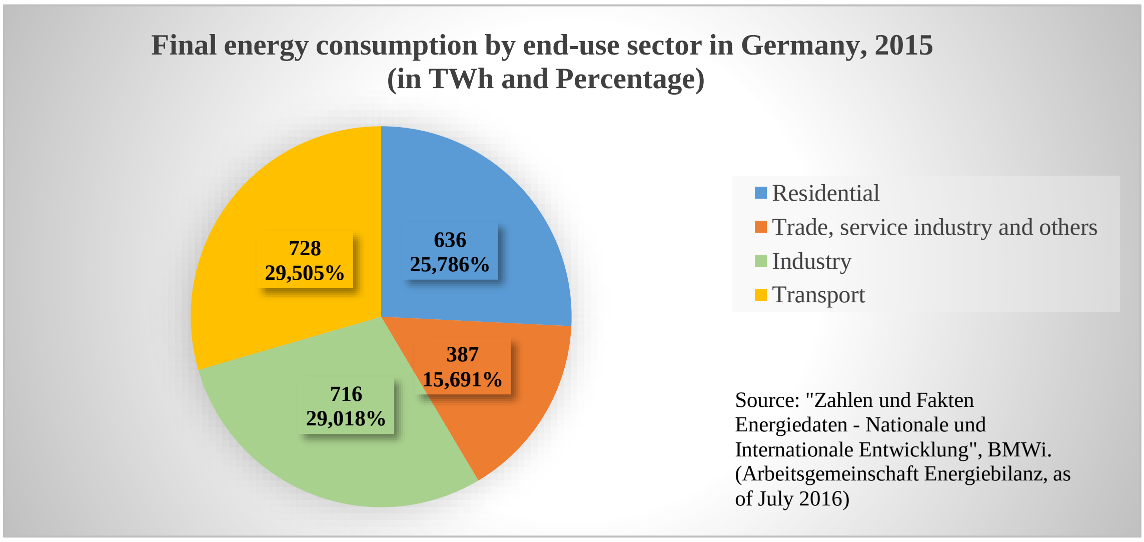

Figure 1.3 Energy consumption by end-use sector in Germany 2015

In the United States, the similar situation is that energy consumed in residential buildings

4 http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tsdpc320&language=en

with 15 per cent of the total was more than that in commercial buildings with 12 per cent of the total (EIA 2017). For developing countries, industrial sector consumes still the highest share of total final energy, for example, China, where more than 70 per cent of energy was consumed for industrial development for rapid infrastructure improvement and economic growth. However, residential buildings consumed almost triple energy (9.3 per cent) than commercial buildings (3.2 per cent) in 2015, and it still possessed the greatest share among all other energy-consumed sectors except industry and transport, which could attribute to its high urbanization rate, as Fig. 1.4 and 1.5 illustrated.

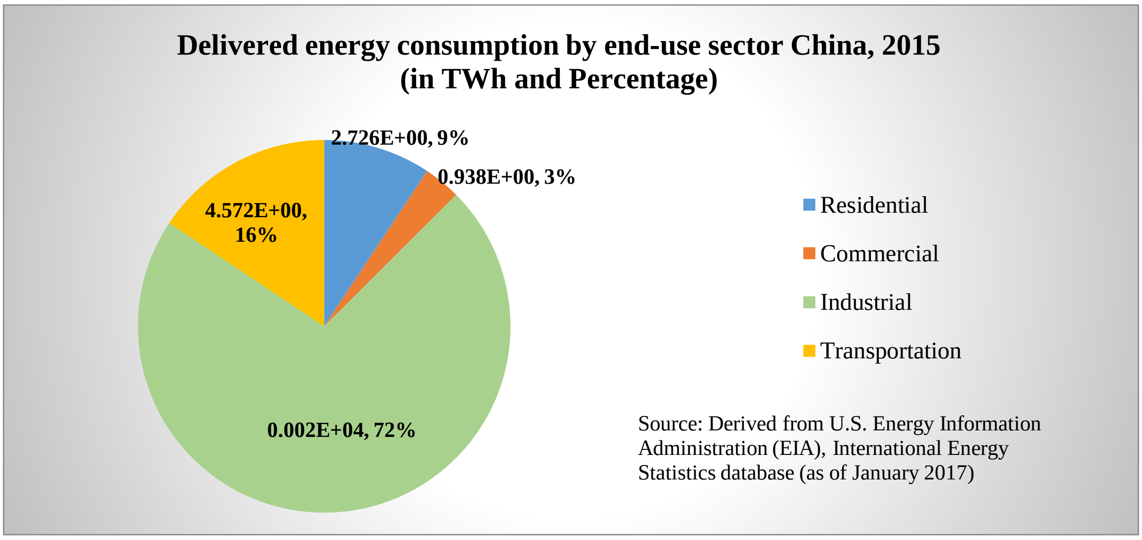

Figure 1.4 Energy consumption by end-use sector in China 2015

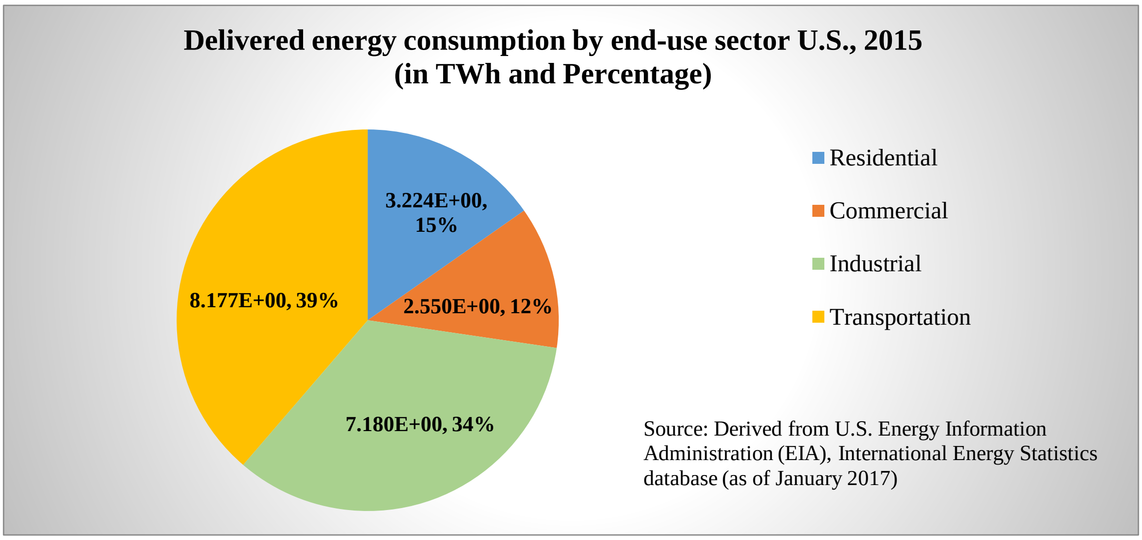

Figure 1.5 Energy consumption by end-use sector in U.S. 2015

From the perspective of climate protection, increasing energy consumption leads to the rise of CO_2 emissions. EIA released in 2015 the CO_2 emissions data that was related to energy consumption in most countries and regions worldwide in 2013. Statistics of energy-related CO_2 emissions from different sectors in worldwide, Germany, China, the U.S., and EU-28 were illustrated as Figures 1.6 - 1.10.

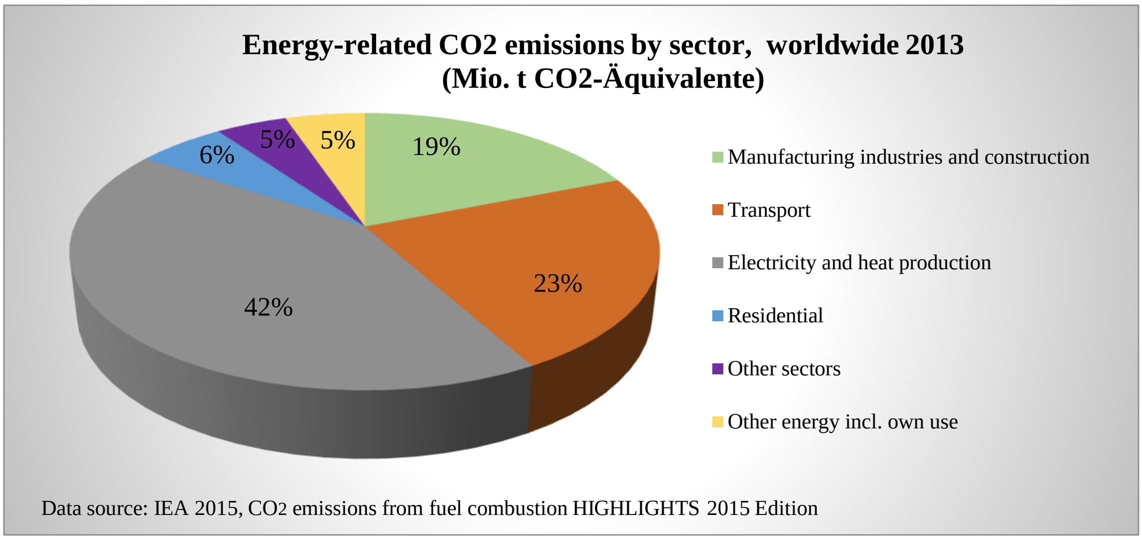

Figure 1.6 Energy-related CO_2 emissions by sector, worldwide 2013.

It was worthy to mention that the average CO_2 share from residential sector stays with upward trend. According to the latest data from IEA in 2016, the 8% of CO_2 emissions in 2014 was produced by residential, but except the 8% net share, there was still 12% which was exhausted through generating heat and electricity for residential sector (IEA 2016, p.9).

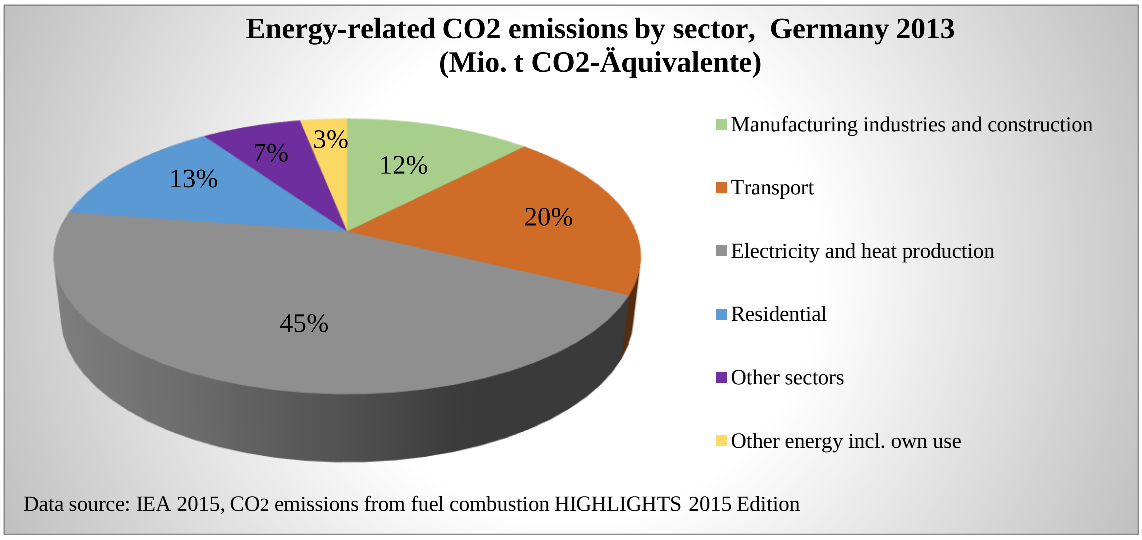

Figure 1.7 Energy-related CO_2 emissions by sector in Germany 2013.

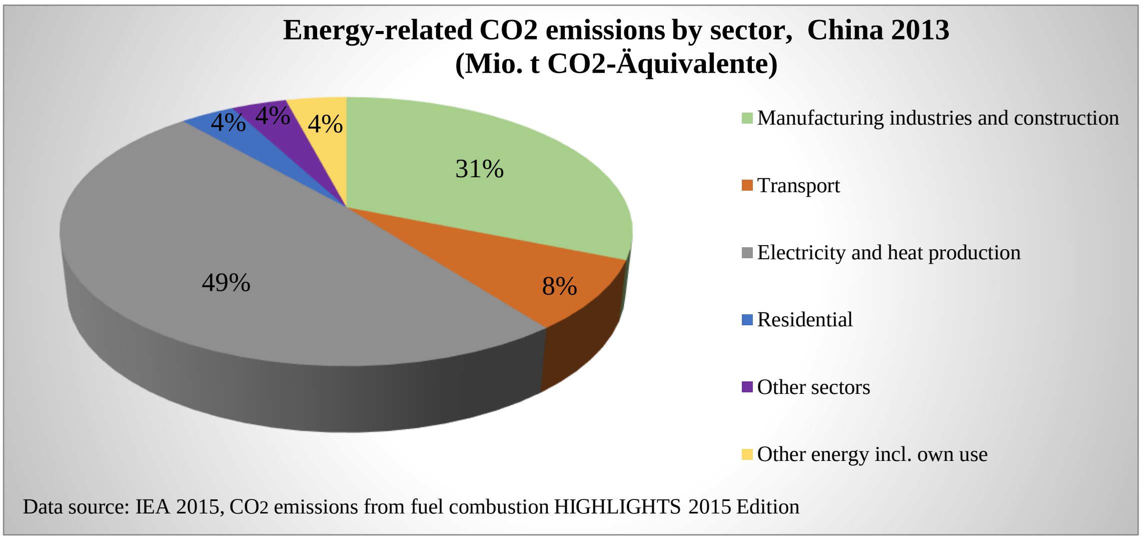

Figure 1.8 Energy-related CO_2 emissions by sector in China 2013.

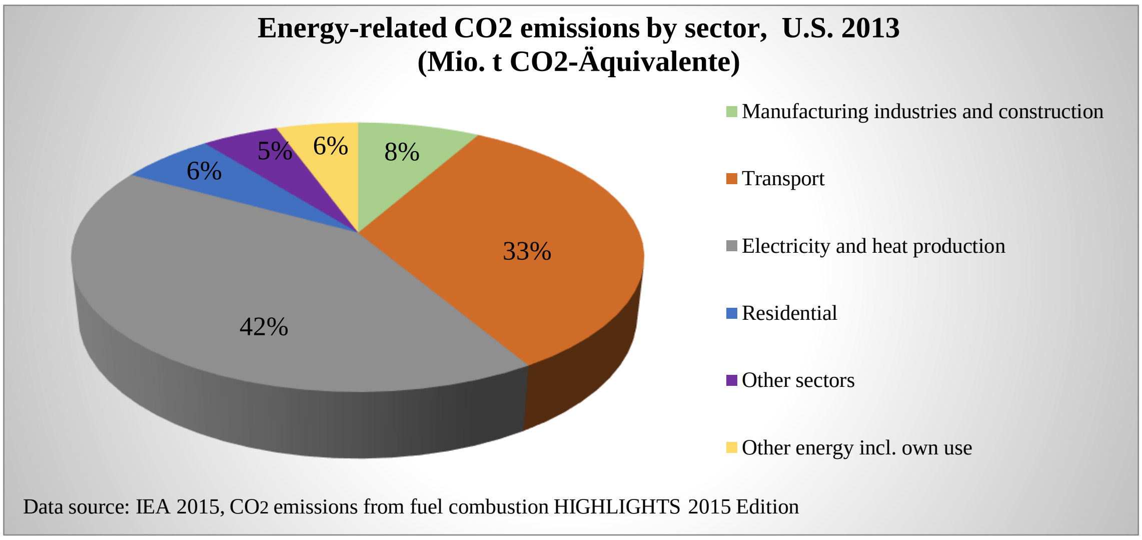

Figure 1.9 Energy-related CO_2 emissions by sector in the U.S., 2013.

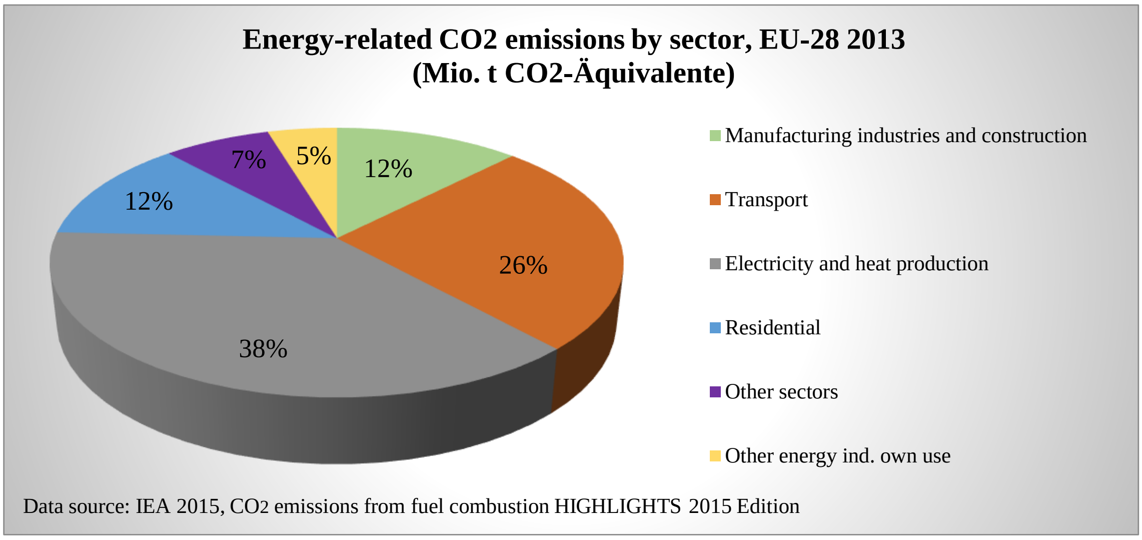

Figure 1.10 Energy-related CO_2 emissions by sector in EU-28, 2013.

The great part of energy consumption in residential buildings contributes to ensuring indoor thermal comfort, in other words, for space heating where are with cold climate, but for space cooling where are with hot climate. Then it follows in order by domestic water heating, lighting, and other household electrical appliances. Nevertheless, the obvious discrepancy of residential energy consumption in quantity has been found out among different households, even though which share the similar natural conditions (e.g., climate, geographical location) and technological support (e.g., building construction, energy equipment) and institutional challenges (e.g., accessibility and affordability of energy saving information and knowledge). This is to some extent explained by the economic disequilibrium among countries or regions, but to a great degree explained by occupant behaviour and awareness towards energy conservation, which is determined by their social background, for example, educational levels, family structure, income levels, and their access to energy-saving information.

Aiming to pursue an efficient energy conservation in the residential sector, there are some original intentions from different perspectives that inspire increasing studies on building energy efficiency, particularly on residential building stocks. For instance, from an economic point of view, on the one hand, the energy costs of households reflect their energy consuming situation in the most direct way and also reflect the price fluctuation of domestic energy to some extent. On the other hand, an increasing energy bill in black and white is one of the most stimulating energy-saving drivers for households, which affects not only people's initiative to spare household energy and also determines how successfully can the energy-efficient technologies and philosophy be developed and implemented. From the environmental point of view, the impacts resulting from residential energy consumption shall not be slid over because they cause not only the instant inconveniency for daily life, but also carry the potential trouble and threat for future generations along with economic pressure for private households and fiscal burden for public authorities due to housing subsidy policies.

The residential energy efficiency has been improved since recent decades remarkably benefiting from the increasing standards, form of building construction (e.g., European standards for sustainable construction or sustainability assessments of buildings, such as EN 15643-1:2010, EN 15643-2:2011, EN 15643-3:2012, EN 15643-4:2012, EN 15643-5:2018), to of the corresponding energy equipment and household electrical appliances. However, an apparent boost of residential energy consumption and costs have been proved to be a common problem because of the rising penetration and oversizing of private energy facilities, the change in floor area for space heating, so-called „larger homes“, which are influenced by individual energy-using behaviour to such a great extent. This unexpected result influences demand-supply-patterns in the energy market. In this context, residential building stocks must be a crucial research area in building energy efficiency.

1.2 Motivation and Objective

Energy in the operation phase of residential buildings enables space heating and cooling, domestic hot water supply, ventilation, lighting, information and communication, which not only meet the basic living needs of humans also improve our living condition in many ways. Stakeholders in different fields all along, such as architecture and civil engineer, real estate, housing politics-maker and private households, as well as building material industry and financial institutes, pursue an efficient residential building energy system and a synergic development model of building energy efficiency.

The basic idea of this doctoral research is to implement a synergy between efficiency instruments and information tools of the energy system in residential buildings, in other words, to combine technological promotion with energy-saving awareness and behaviour of occupants. Energy instruments refer to the objective part that contributes to improving energy efficiency through technical retrofit and modernization, and information tools focus on transferring energy saving knowledge, which works for changing occupants awareness and behaviour towards their household energy consumption.

An Integrated Retro-commissioning (IRc) methodology is identified in this research. As a derivative methodology of Retro-commissioning, the IRc considers occupants behaviour when analysing residential energy consumption. In addition, energy efficiency indicators in residential sector will be analysed to identify the energy-related information that is necessary for further modelling and simulation.

In general, the goal of this research is to develop a portfolio that can provide a comprehensive analysis of residential building energy efficiency referring to technical feasibility, social acceptability, economic profitability and political support, thus to bridge the gap of credibility and accessibility between energy-related residential building elements and people who living in. Specifically, there are four objectives that are pursued in this doctoral research. The first objective is to derive energy efficiency assessment measures based on the building technological improvement. Analysis of building construction elements is conducted to find out the latent defects resulting in energy leaks during the residential building operation. For example, an insufficient insulation of building façade, a weak housing ventilation system etc. Those hidden troubles exist especially in existing stocks that are a shortage of regular maintenance. Meanwhile, it is proposed to underline the impact of reasonable architectural design on full use of natural light and solar energy, because which could be a supplement for home energy supply. The second objective is to evaluate the impacts of the socio-economic background on energy-related behaviour and attitudes of occupants in residential building stocks. This analysis focuses on a long-term interest of raising awareness of energy conservation from the perspective of internal factors, which means mainly their social background of households. An analysis is conducted based on the investigated data on the energy efficiency of social housing in Darmstadt, Germany. A system about energy conservation consciousness is discussed to explore household energy saving potential through changing user behaviour, e.g., by means of setting thermostats point appropriately, adjusting reasonable ventilation rate etc. The third objective, also the main goal is to establish a multi-criteria assessment model that allows stakeholders to better understand and deal with the problems of residential building energy efficiency, to efficiently analyze and assess the applicability and validity of the potential energy-saving measures in a holistic way. The last objective is to develop a sensibility analysis to determine the interaction between occupant behaviour and residential energy efficiency.

Residential energy efficiency is of interest as it depends on both the objective part, i.e. technological conditions and the subjective part, i.e. occupants behaviour. This research thesis is supposed to provide a guidance to the relevant stakeholders about how to improve energy performance in residential buildings in a cooperative way. The new methodology IRc and cost-benefit-analysis as well as behaviour profile model are proposed to be meaningful for all relative stakeholders, not only for those directly affected (e.g., occupants, building owners), but also for building designers (i.e., architects, civil and energy engineers) who are in charge of building construction from the beginning, aiming for a reasonable and sustainable energy consumption. The outcomes also expect to be instructive for decision maker committed to housing and residential energy issues and regulation.

1.3 Research focus and structures

This doctoral research works on investigating energy performance in residential buildings with a focus on energy and resource management by means of technological improvement and occupant behaviour change. This focus begins from analyzing the current situation of energy using pattern in residential buildings in Germany according to the existing studies along with a brief comparison with China and the U.S., with regard to some external conditions like building insulation materials, residential building standards and housing policy etc. The proposed methodological analysis and performed simulation models are developed under the consideration of the above mentioned external and internal factors.

This dissertation is divided into seven chapters that focus on three main topics. In **chapter one** an introduction states research background and problem statement, research motivation and objectives, as well as the structure of the dissertation.

A fundamental concept is introduced in **chapter two**, which refers to a brief outline of the research procedure and strategies, i.e. the research phases of this doctoral thesis.

In **chapter three**, the current situation of residential energy consumption is described and the encountered problems and barriers are identified, through analyzing the internal and external factors influencing building energy performance. This is also <u>the first research topic</u> of this dissertation. More specifically, issues such as growth in population and urbanization, change of consumption patterns of residents, diversity of social-culture characteristics and disparity of regional energy and housing policies, as well as general problems like climate change or energy shortage, are introduced based on the status quo within the scope of Germany and the average level of EU, China and the USA. In addition, the relevant stakeholders and their obligation for and interests in energy conservation are analyzed respectively, which interpret the concrete challenges for all the stakeholders, involving technical and economic limits as well as the challenge of social participation.

The **fourth chapter** clarifies the methods and approaches to the optimization of energy efficiency in residential buildings. As <u>the second research topic</u>, it introduces the Integrated Retro-commissioning method that is developed for meeting the specific requirement on residential buildings. The applicability and feasibility of the proposed method must take technical and socio-economic factors and other regulatory issues into account.

A case study with simulation modelling is conducted in **chapter five**, which consists of data processing, modelling and simulation, and sensibility analysis under the framework of simulation tools and some hypothetical conditions. As <u>the third research topic</u>, it is derived from this chapter by implementing the theoretical methodology into the simulation models, which benefits to verify the assessment criteria and analytical methods based on the simulation results.

Chapter six is a discussion part that combines the work from the proceeding chapters. This discussion refers to the driving forces, and the problem and barriers appeared during the work procedure. It reveals the inadequate part of proposed methods and other conservation possibilities during energy consuming in residential buildings, to pursue optimal interventions and improve residential building energy efficiency taking the involved requirements and limitation into account.

Conclusion and outlook for the study on residential building energy efficiency are conducted in **chapter seven** that summarizes this research work and lists the main conclusion, as well proposes further research directions.

2 Fundamental principle

Energy consumption in the residential sector has been proved as a major contribution to tackling unreasonable energy allocation and climate change (Oladokun and Odesola 2015, Munksgaard et al. 2000, Zhao et al. 2012, Feng et al. 2011, Guo 2017). This doctoral research aims for a holistic and integrated approach or approach matrix that can predict, analyse and handle the existing and potential problems with respect to energy efficiency in residential buildings. The methodology and approaches proposed in this dissertation derive from a set of in-depth investigation of abundantly available studies on residential energy efficiency. Meanwhile the identified problems in the former projects about residential building energy efficiency motivate further work in this doctoral study, which refers mainly to identify the responsibility of stakeholders towards an efficient residential energy using with regard to technological improvement and behavioural optimization.

2.1 Research concept

Technical building retrofitting and change of occupant behaviour make up the core concept of residential energy conservation in this doctoral research. The profile of residential energy consumption can be simplified described with Equation 2-1 below, which interprets the influencing components when calculating the actual household energy demand,

$$E_{ac.}(x) = E_{th.}(x) \cdot \{\eta_i, \delta_i, \zeta_i\} \tag{2-1}$$

where

$E_{ac..}$: actual residential building energy consumption. [kWh/yr]

$E_{th.}$: theoretical energy demand for residential building, which is determined based on the design standards of residential indoor environment and energy-related floor area. [kWh/yr]

η_i: thermal characteristics of building components, which shall take the discount of thermal performance due to disrepair. η_i is allowed to be a weighted value because it refers to different construction components with various thermal characteristics (e.g., thermal transfer coefficient U-value, thermal resistance value R-value, Solar Reflectance Index[5] etc.). In addition, the impact of building orientation shall not be ignored.

[5] https://www.usgbc.org/glossary/term/5590

δ_i: efficiency factor of energy equipment and appliances, such as HVAC (including heating system, boiler, thermostat, ventilation and air conditioning), water heater, lighting and domestic electrical appliances. δ_i influences the internal heat gain during using the household appliances and lighting.

ζ_i: energy-related behavioural elements of occupants, which influence the household energy consumption and indoor air quality. This is a subjective factor with high random nature resulted from the social background of occupants and the social environment they living in. ζ_i influences the internal heat gain from occupants owing to occupancy rate and energy-related indoor activities.

i: refers to different involved influencing elements (i.e. external and internal), which are introduced as energy efficiency indicators and applied as parameters for technical and behaviour-based energy consuming simulation in this dissertation.

x: investigated residential building case.

In addition, climatic factors (e.g., heating degree days HDD/cooling degree days HDD) and other possible influencing factors, such as floor areas for heating, energy prices, residential energy policies and regulation, availability of renewable energy in residential sector etc.

Residential building energy efficiency improvement is implemented under both restrict conditions: one is design norms and standards for building energy efficiency retrofitting, another is a compromise among various stakeholders‘ requirements on costs and benefits. In Germany, norms and standards of thermal design are accepted for the framework of calculation and simulation towards determining the primary energy requirement of the residential unit in both annual and monthly balance sheets. The basic building energy efficiency standards applied in this doctoral research principally involve the thermal performance of residential buildings, as the final energy consumption for space heating in German households accounted for about 70 per cent of the total according to statistics from BMWi in May 2017. DIN[6] V 4108[7] and DIN V 18599[8] as the main design standards for German building thermal performance and other domestic energy demand assessment.

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[6] DIN: German Institute for Standardization (Deutsches Institut für Normung e.V.), is the German national organisation for standardization and is the German ISOn member body.

[7] DIN V 4108: Wärmeschutz und Energie-Einsparung in Gebäude (in English: Thermal protection and energy economy in buildings)

[8] DIN V 18599: Energetische Bewertung von Gebäuden - Berechnung des Nutz-, End- und Primärenergiebedarfs für Heizung, Kühlung, Lüftung, Trinkwarmwasser und Beleuchtung (in English: Energy efficiency of buildings – Calculation of the net, final and primary energy demand for heating, cooling, ventilation, domestic hot water and lighting)

The part six of DIN 4108 (i.e. DIN V 4108-6[9]) provides the calculation concept of heating energy demand in buildings with Equation 2-2. A sum of the annual heating demand Q_h, the annual heat demand for domestic hot water Q_w, and the heat losses of the heating and hot water heating system Q_t, taking the account of energy input Q_r generated by energy supply system (DIN V 4108-6, 2003, pp.12-14),

$$Q = Q_h + Q_w + Q_t - Q_r \tag{2-2}$$

where

Q: total annual heat demand of buildings, [kWh/a]

Q_h: annual heating energy demand, calculated with the simplified procedure, [kWh/a]

$$Q_h = 66 \cdot (H_T + H_V) - 0.95 \cdot (Q_S + Q_i) \tag{2-3}$$

H_T: specific transmittance heat loss through building elements, such as walls, windows, doors, floors and others. It depends mainly on three indices: the overall heat transfer coefficient, i.e. U-value [W/(m²K)], area of exposed surface A [m²] and temperature difference t_{i-0} [°C] between internal and external surface. The relative specific heat transfer coefficient due to ventilation allows being determined in accordance with DIN EN ISO 13789[10], §4, [W/K]

H_V: specific heat loss caused by ventilation. It is determined by different parameters, such as specific heat capacity of air c_p [kJ/(kg·K)], the density of air ρ [kg/m³], air volume flow q_v [m³/s], and temperature difference t_{i-0} [°C] between inside air and outside air. The relative specific heat transfer coefficient due to ventilation allows being determined in accordance with DIN EN ISO 13789, §5, [W/K]

66: HDD-factor, F_{Gt}, which results from the number of heating degree days (≈ 185 days[11], the number of days when the difference between outdoor and heating temperature is below 10°C) multiplied

[9] DIN V 4108-6 (June 2003): Thermal protection and energy economy in buildings - Part 6: Calculation of annual heat and annual energy use.

[10] DIN EN ISO 13789 (April 2008): Thermal performance of buildings – Transmission and ventilation heat transfer coefficients-Calculation method (ISO 13789:2007).

[11] https://www.uni-due.de/ibpm/Aufgabensammlung/SchemazurEnEV.pdf, pp.10-11.

by conversion factors (= 0.024, from day to hours and watts to kilowatts) and a reduction factor (= 0.95, which is a reduction factor for night setback of heating system). This value is used in heating-period method, which is identified in EnEV § 3 Abs. 2 Nr. 1 and Annex 1 Nr.3.

0.95: flat-rate utilization factor of heat gains,

Q_S: solar heat gains due to direct solar radiation through transparent components of buildings, such as windows. It is determined by the orientation and size of the windows, the degree of energy transmission of the glasses as well as the effects of the shading and the soiling of the panes[12]. It is determined by the total solar irradiations depending on building orientation, the total energy transmittance (particularly for vertical irradiation) determined by technical product specifications or according to DIN EN 410: 2011-04[13], and the area of windows with the orientation A_i [m^2], [kWh/a]

Q_i: internal heat gains, which consist of the waste heat from people living in and the energy-related equipment, for example, lighting, home appliances in kitchen and other living space. Equation 2-4 formulates the calculation for it (Staniszewski and Gierga 2016, p.8), [kWh/a]

$$Q_i = q_i \cdot A_N \cdot 24/1000 \cdot t \tag{2-4}$$

where,

$q_i = 5\ W/m^2$ for residential building [W/m^2]

A_N = effective energy-related floor areas [m^2]

t = days of the heating period per year [-]

which is allowed to be simplified, as Equation 2-5:

$$Q_i = 22 \cdot A_N \quad [kWh/a] \tag{2-5}$$

12 https://www.baunetzwissen.de/glossar/s/solarer-waermegewinn-1074411

13 DIN EN 410 (April 2011): Glass in building - Determination of luminous and solar characteristics of glazing.

where,

the factor 22 as a flat-rate value is calculated with the following background: it is assumed that the internal heat gain of residential buildings is 5 W/m^2 and a heating period per year accounts for 185 days, therefore the factor results from,

$5\ [W/m^2] \cdot 185\ [d] \cdot 0.024\ [kWh] = 22.2 \approx 22$

About effective energy-related floor area A_N [m^2], it is determined by heated building volume V_e, as Equation 2-6 shown,

$$A_N = V_e \cdot 0.32/[m] \qquad (2\text{-}6)$$

where,
V_e [m^3] is the heated building volume, which is the volume enclosed by the heat transferring surrounded area A and determined through A multiplies ceiling height h_g [m],

$$V_e = A \cdot h_g \qquad (2\text{-}7)$$

A is determined in accordance with Annex B of DIN EN 13789, i.e. the peripheral area,

and then

$$A_N = A \cdot h_g \cdot 0.32/[m] \qquad (2\text{-}8)$$

with 2,5 m $\leq h_g \leq$ 3.0 m, for a residential dwelling unit in general. However, if $h_g \leq$ 2.5 m or $h_g \geq$ 3,0 m, according to Annext 1 Nr. 1.3.3 sentence 2 of EnEV 2013 A_N shall be[14],

$$A_N = (1/h_g - 0.04[m^{-1}]) \cdot V_e \qquad (2\text{-}9)$$

Q_w annual heat demand for water heating, which depends on several parameters, e.g., volume-specific heat capacity of water $(\rho c)_w$ = 1.161 kWh/($m^3 \cdot K$), volume of warm water during the calculation period V_w [m^3],

[14] http://www.enev-online.com/enev_2014_praxisdialog/140811_19.04_dibt_ermittlung_gebaeudenutz-flaeche_an.pdf

the temperature-difference θ_{w-0} [K] between the consuming-targeted discharged hot water and the water before entry into hot water system. This amount can be determined according to DIN EN 832[15], [kWh/a]

Q_t heat loss of energy-related equipment for heating and DHW supply in a building, except energy loss during distribution, storage and generation, [kWh/a]

Q_r: energy input to the heating system from regenerative source by additional equipment, excluding the amount of energy directly from solar heat gains and heat-recovery from ventilation systems, which is included in annual heating energy demand Q_h in general. Calculation of Q_r refers to DIN 4701-10[16]. [kWh/a]

The equation above describes energy balance in residential building unit that can be depicted in Fig. 2.1, which visualizes the general residential energy flow that is consumed, gained and wasted.

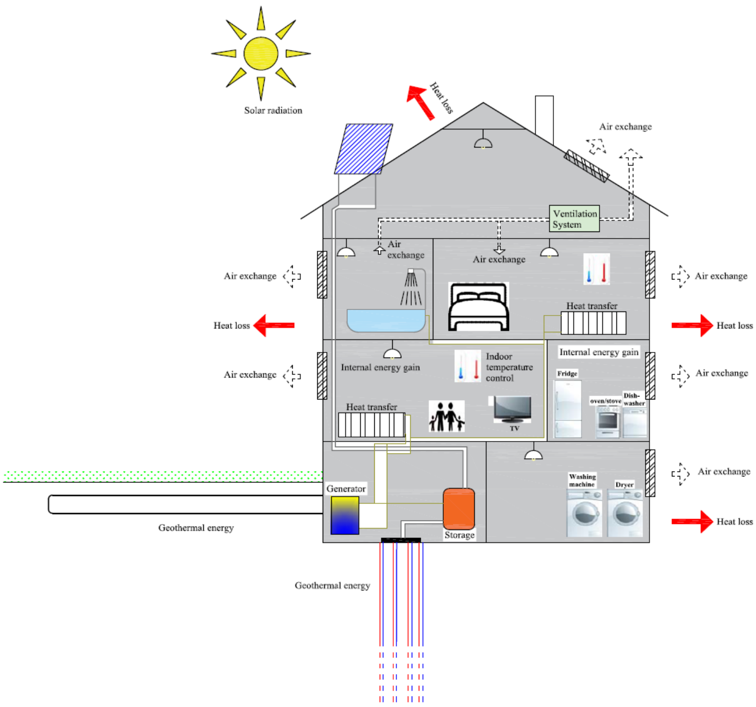

Figure 2.1 Energetically characteristic values of residential building/housing

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[15] DIN EN 832: Thermal performance of building - Calculation of energy use for heating-Residential buildings.

[16] DIN EN 4701-10 (August 2003): Energy efficiency of heating and ventilation systems in buildings - Part 10: Heating, domestic hot water, ventilation.

A compromised solution for optimization of energy efficiency in residential buildings is inevitable owing to the conflicting interests (Shao 2015) and fragmented expertise (Yudelson 2010), but a rational compromise is also effective for the implementation of energy saving measures, which can address all involved stakeholders‘ requirements, evoke their attention and create their awareness under limited costs, as far as possible. Miller and Buy (2008) indicated in their study on the commercial building that energy retrofitting measures could not be successfully implemented without a full and effective participation and cooperation among stakeholders. However, focusing on the operational energy of buildings, the „mutual influence or interdependence“ among stakeholders related to energy consumption in residential buildings is more complex than that in commercial buildings. It is reflected especially through the diversity of occupancy rate and occupants interaction with energy-related building components and equipment.

Based on the collected data about residential building energy consumption and the behavioural features of occupants, this doctoral research is to analyse and verify the indoor thermal comfort and to stretch forward optimized energy performance (i.e. reduced energy consumption, improved indoor air quality and living satisfaction etc.) through adjusting the occupants’ schedules on occupancy and other energy-related indoor activities. This is an iterative process with simulation modelling. A subsequent discussion on simulation results is conducted towards the following key questions that attempt to be clarified in this research and need further study for more comprehensive solutions:

- The critical stakeholders related to the energy efficiency of residential buildings, their functions and constraints for reducing energy consumption.

- The nature of residential energy problem during the operation phase is arguably a problem between energy facilities and occupants, i.e. the interaction between the both. Therefore, an integrated assessment concept for energy efficiency in residential buildings is developed to put the occupant behaviour as an important parameter into any technological retrofitting solution, which thus takes the requirements of critical stakeholders into account for striving for high participation and successful implementation.

- Suitable energy saving measures in residential buildings are labelled with technical feasibility, economical affordability, as well as reliability and acceptability by occupants. Traditional cost-benefit-analysis is not enough to reflect the satisfaction of occupants, which influences the implementation of energy saving measures in turn. Therefore, with the simulation tool a satisfaction rate of occupants on their indoor environmental quality can be calculated, which depends on a range of factors, e.g., performance of energy equipment, energy-consuming behaviour, energy prices, and weather etc.

- A portfolio of residential energy efficiency is the ultimate pursuit of this research, aiming to delve into the influencing factors and specify the framework of energy efficiency optimization in residential buildings concerning consumption and savings, environmental impact and indoor environmental quality.

An efficient energy performance in residential buildings can be achieved in a sustainable way, in the event that the energy saving measures are developed with a full consideration of stakeholders‘ features (e.g., interests, obligations, requirements, and limits), as illustrated in Fig. 2.2. The research model in this dissertation is established with energy-related information based on limited data from research projects on social housing energy efficiency in Germany, therefore, owing to data protection there is some assumption for modelling and will be indicated for the following simulation.

Figure 2.2 Fundamental principle of sustainable energy performances of residential sector

2.2 Literature review

The focuses of this doctoral research basically consist of technological improvement and behavioural optimization. A literature review is conducted towards both sub-focuses, which involve the study on residential energy efficiency in different cases with various external and internal influencing factors, as well as experiencing problems and solutions (e.g., analytical methods, predictive models, assessment criteria). The past and current state of studies on residential energy efficiency are specified through a literature review, which contributes to clarify the further research direction in this area. The main literature review covers the following topics that are involved as the reference in this dissertation:

- Indicators in relation to residential building energy efficiency.
- Methodology for building energy efficiency development.
- Energy efficiency measures.
- Impacts of occupant behaviour on residential energy efficiency.

With the support of literature review, several research aspects are enlighted and advanced in this research:

- The engagement of occupants plays a critical role in energy efficiency in residential buildings. The analysis on occupant behaviour involves the schedules of occupants related to energy consumption, which influence the energy performance of invested energy saving measures and their own indoor environment quality.
- Energy efficiency retrofitting on residential building involves different stakeholders, which leads to the desire and necessity of building energy design through a holistic and integrated approach.
- The characteristics of building energy technology and the requirements of stakeholders are main underlying research concerns for exploring the energy saving potential in residential buildings.

The fundamental concept of this doctoral research induces an integrated analysis methodology and optimization techniques to prove the importance of taking the interaction of occupants with building energy performance full into account. A newly developed analysis methodology referring to integrated energy efficiency approach about multiple concerns is detailed in the following chapter.

3 Challenges and opportunities

Residential buildings with high energy performance, which aim to provide the best indoor environment quality with the lowest cost and endeavour, are often pursued by all involved stakeholders. Although various energy saving measures (ESMs) and building environmental assessment methods are developed and implemented for residential buildings, the decision to choose the specific measures seems to be arbitrary in many cases, and how to take full advantage of ESMs remains still in question and uncertain. A significant gap persists between the designed building energy performance and the actual energy consumption or demand. Reasons causing the gap are complex and multiple, which relate to the technology (i.e. building construction and energy facilities), behaviour (i.e. the interaction between residential building occupants and building energy system), and management (i.e. efforts of energy provider for optimal energy supply and building energy balance). In addition, there are the influences from energy market, local economic development, climate, and even urbanization situation that is particularly interesting for developing countries. Based on the perceived reasons and background mentioned before, the negative impacts resulting from low residential energy performance refer not only to the amount of energy consumption and costs, but also to the type and proportion of different energy carriers (i.e. conventional fossil fuels vs. renewable energy), as which determines the environmental impact of residential buildings. In a broader context the efficiency of energy management system, the rationality of resource allocation, appropriate technical reform, sufficient financial support and effective policy guidance shall not be overlooked. It is noteworthy that the influencing factors and consequences affect and presence never one-way, but an interaction.

The core challenge brought therefrom is how to achieve a sustainable living environment against the conflicting requirements of stakeholders with the help of their active engagement, so as to improve the residential building energy efficiency in a holistic system. Specifically, the concrete challenges refer to clarifying the impacts and barriers accurately, diagnosing the problems purposefully and minimizing vague measures that could be too general to be suitable for residential building energy issues with different requirements. And before developing programmatic responses to these challenges and exploring opportunities in context of energy, economics and social issues, an analytical work on those influencing factors is performed at first not only for a clear understanding the status quo and the research aspiration, but also for achieving a clear vision and scientific strategies, as well as for supporting optimization performance and decision-making process.

Keywords of chapter 3:
Thermal characteristics of residential building construction, socio-demographic and socio-economic background, building energy conservation codes, housing policy, energy policy of residential buildings, rebound effect

3.1 Influencing factor: Urban-economic condition

The population and economic growth is the main reason for the increase in conventional fossil fuel and the resulting CO_2 emissions (IPCC 2007, York 09-2007, York 12-2007, Martínez-Zarzoso et al. 2007, Poumanyvong 2012, Zhao et al. 2012). The increasing urbanization is firmly regarded as an important factor resulting in the growing demand on fossil energy and therewith increasing CO_2 emissions.

Urbanization is described as a process, by which large numbers of people change their living areas from rural to urban and permanently live and product in urban areas. It is defined as the percentage of the total population that lives in urban areas by the United Nations Section on Population Division, Estimates, and Projects (World Urbanization Prospects: The 2011 Revision. UN). As a phenomenon and inevitable trend of economic and social modernization, urbanization is not only the process of transferring rural labor from an agricultural-based economy to urban areas where industrial and service sectors predominate, but also the process of the structural transformation of rural areas into urban areas, it could be described as a demographic indicator that changes human behaviour and attitude, thereby influencing their household energy use patterns (Barnes et al. 2005, Poumanyvong et al. 2010).

The considerable debate on to which extent urbanization could influence energy consumption and environmental pressure has been engaged since recent decades (Dietz and Rosa 1997, Cramer 1998, Cramer and Cheney 2000, York et al. 2003, York 2007, Frederiks et al. 2015, Yanagisawa 2016, Ota et al. 2017). The urbanization-emission elasticity value[17] (de Leon Barido and Marshall 2014) is used to assess the influence of urbanization on CO_2 emissions. The urbanization-emission elasticity value is regarded as an economic indicator at national, region and household level related increase of GDP or private income and the resulted increase in energy consumption. However, it may depend on the strength of environmental policy, which means, if given an improved environmental policy and a sound macroeconomic policy and energy management system, urbanization could have a beneficial or a less negative impact on energy consumption and emissions (Barido and Marshall 2014). That was reflected by many studies on the relationship between urbanization and energy consumption as well as emissions, with taking the economic condition into account. For example, research by Poumanyvong et al. provided their research results of the impact of urbanization on total energy use and CO_2 emissions with consideration of different levels of development using the "Stochastic Impacts by Regression on Population, Affluence and Technology" (STIRPAT[18]) model. The results

[17] Urbanization-emission elasticity value: this value means that a percentage change in urbanization leads to a more than proportionate change in CO_2 emissions. For example, the urbanization-emission elasticity value is 0.95 means that a 1% increase in urbanization correlates with a 0.95% increase in emissions.

[18] http://stirpat.msu.edu/

came from their research on a balanced panel dataset of 99 countries over the period 1975-2005 that showed the urbanization elasticity of energy use was lowest in low-income group with negative number, i.e. urbanization contributed to the reduction of energy use in this group, this phenomenon was also proved in their another research report in 2012 (Poumanyvon et al. 2012). It could be attributed to on the one hand the shift of energy sources in these low-income households with increasing urbanization from inefficient traditional fuels (such as some non-commercial energy sources: firewood, animal waste and agriculture waste) to commercial but non-renewable energy (e.g., coal, petroleum and its products), on the other hand, more possibilities to assess efficient energy-related technologies at home and better access to information and means about home energy conservation. However, the CO_2 emissions from low-income household first fall and then rise along with the increasing urbanization, which could be attributed in particular to the high carbon-intensity of non-renewable energy carriers. In both middle- and high-income group the elasticity value is positive, i.e. increasing urbanization caused more energy consumption in all (Poumanyvong et al. 2010).

In addition to the population growth owing to urbanization, CO_2 emissions may depend more on the structural energy use and environmental policy, in concrete, it is not absolute that more energy consumption from high-income households cause more emissions, since high income group would like to shift toward low carbon fuels and use more energy-efficient appliances, and they have more access to energy conservation information. Lower elasticity values are proved among the three income levels in countries with strong environmental policy than those in countries with weak environmental policy (de Leon Barido and Marshall 2014). Mazur in his research suggested a simplified calculation to introduce the connection between urbanization and consumed energy, i.e. it could be described by two main factors: per capita energy consumption e and total population P, which produce the total energy consumption by the nation in a year E (Mazur, 1994), among which the e depends on more than urbanization's impacts, and in particular for residential building energy consumption, e is affected by household structures and backgrounds as well as the individual characteristics of occupants to a great extent. Fig. 3.1 depicts the urbanization process over the past half-century in the world. Since 2005 the number of urban population exceeded the rural population for the first time and this trend continues.

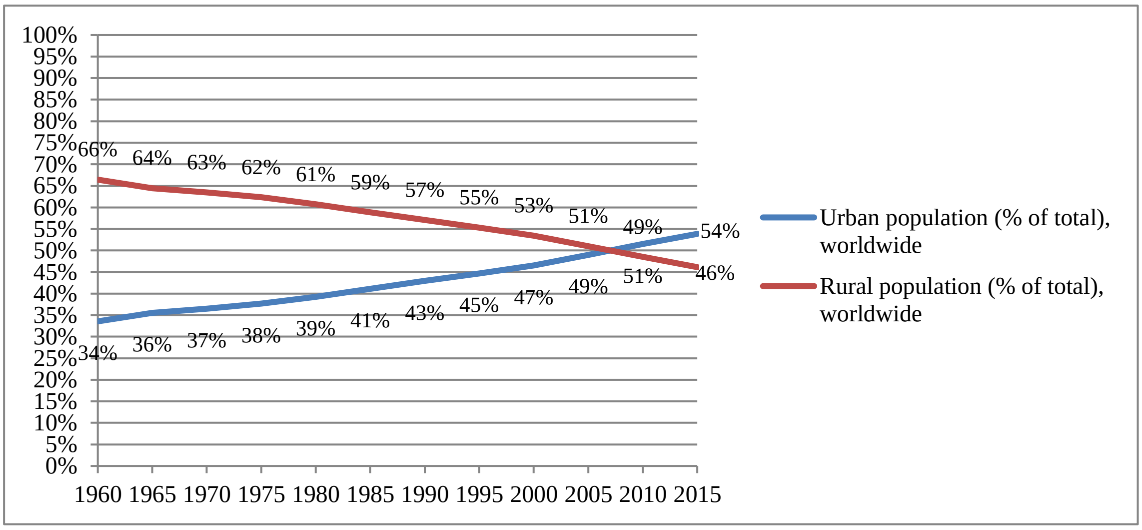


Figure 3.1 Trend of World Urban and Rural population rate 1960-2015 (Data source: World Development Indicators. The World Bank, the latest update on 10th August 2016.)

Rapid urbanization exists mostly in developing countries or others in their economic transition. For example China, where went through an excessively rapid urbanization (excl. Hong Kong, Macao and Taiwan) from 1990 to 2012, the urbanization rate in China mainland has doubled, from 26% to 52%, as in Fig. 3.2 illustrated. It therefore caused the increasing degree of residential energy consumption was much steeper than the growth rate of urban population, as reported by EIA in its International Energy Outlook 2016 (EIA 2016), as shown in Fig. 3.3.

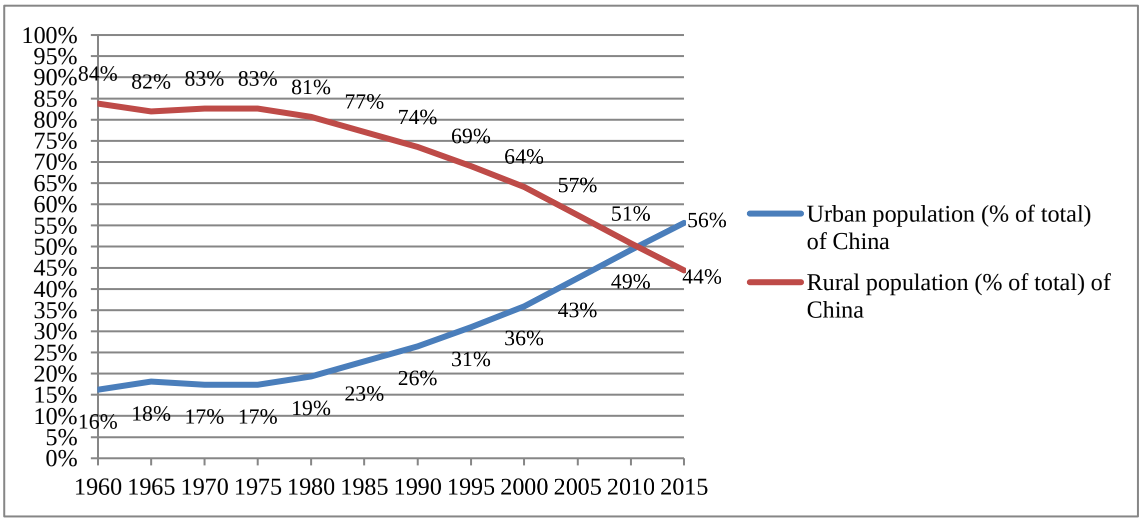
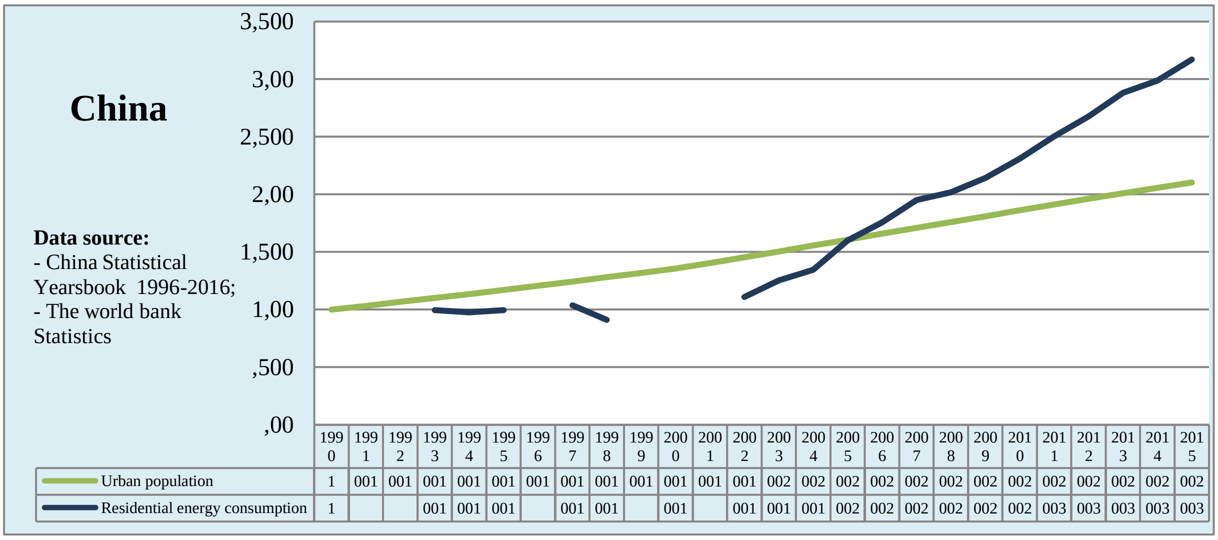


Figure 3.2 Trend of urban and rural population rate of China 1960-2015 (Data source: World Development Indicators. The World Bank, the latest update on 10th August 2016.)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Urban population	1	001	001	001	001	001	001	001	001	001	001	001	001	002	002	002	002	002	002	002	002	002	002	002	002	002
Residential energy consumption	1			001	001	001		001	001		001		001	001	001	002	002	002	002	002	002	003	003	003	003	003

Figure 3.3 Residential energy consumption and urban population growth in China, 1990-2015[21,22], (index: 1990=1.0)

By contrast, the process of urbanization in developed countries was not so obvious, although the urban population has continued to increase in terms of the declining rural population. Therefore it led to actually no remarkable rise of residential energy consumption there, due to the effective energy-saving technologies and policies the energy consumption of residential sector in those countries appeared downtrend slightly. For example, the urbanization of Germany and the United States had also moved forward since a few decades ago, just very slightly in comparison with China and other developing countries, as shown in Fig. 3.4 and 3.5 (Germany), Fig. 3.6 and 3.35
7 (USA).

[21] http://data.stats.gov.cn/english/easyquery.htm?cn=C01

[22] http://www.stats.gov.cn/english/statisticaldata/AnnualData/

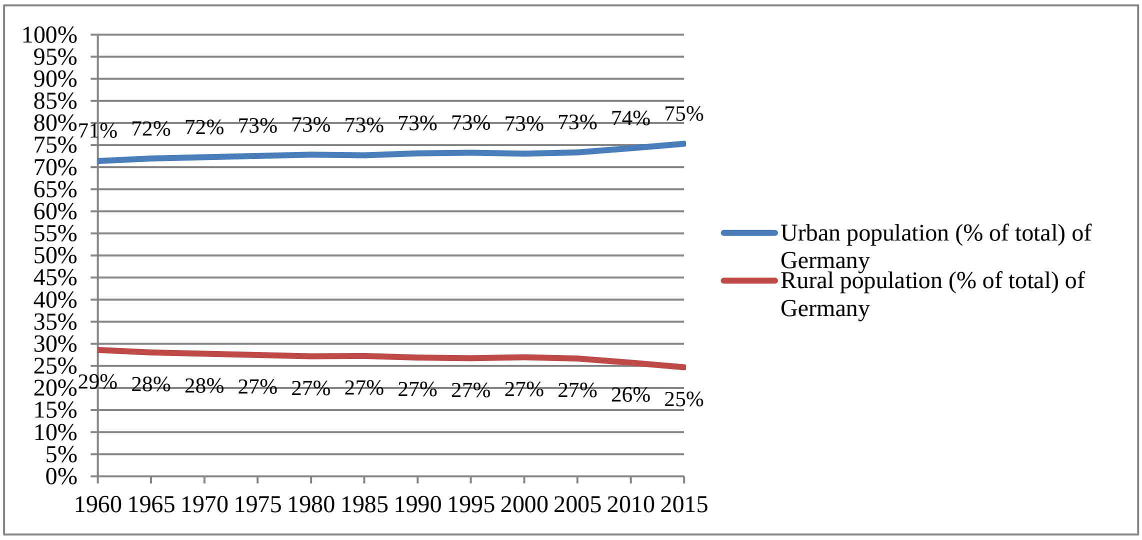


Figure 3.4 Trend of urban and rural population rate of Germany 1960-2015. (Data source: World Development Indicators. The World Bank, the latest update on 10th August 2016.)

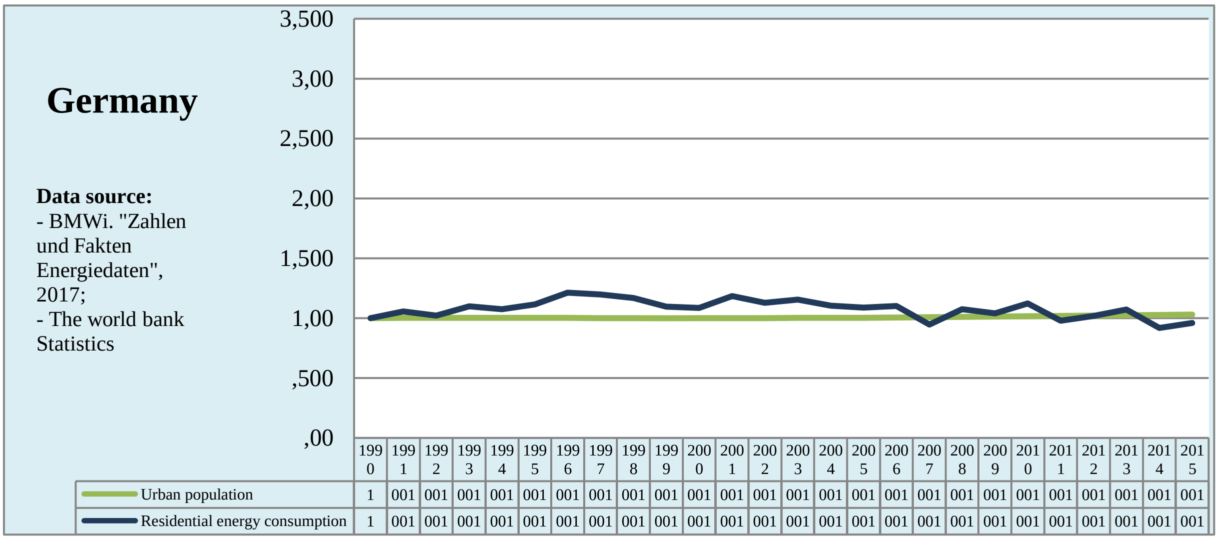


Figure 3.5 Residential energy consumption and urban population growth in Germany, 1990-2015[23]. (index: 1990 = 1.0)

[23] http://www.bmwi.de/Navigation/DE/Themen/energiedaten.html

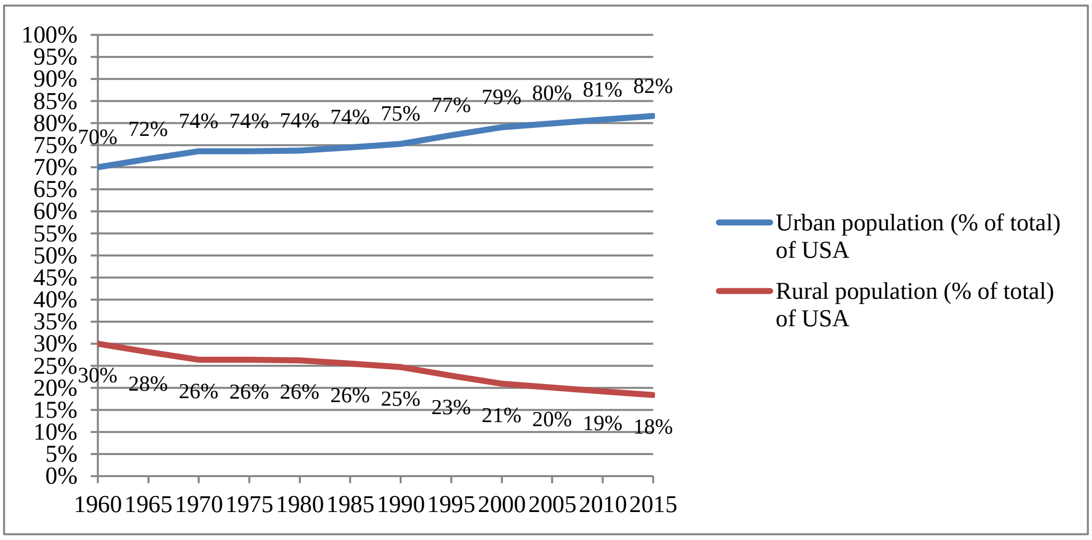


Figure 3.6 Trend of urban and rural population rate of USA 1960-2015. (Data source: World Development Indicators. The World Bank, the latest update on 10th August 2016.)

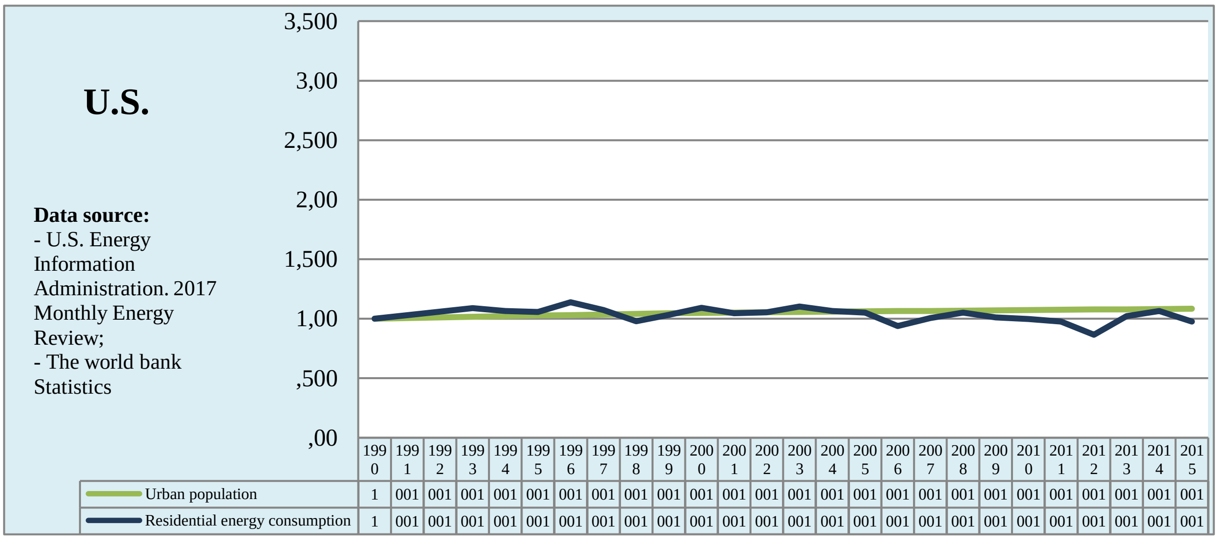


Figure 3.7 Residential energy consumption and urban population growth in the U.S., 1990-2015[24]. (index: 1990 = 1.0)

Urban density and spatial dispersion are key determinants of residential energy consumption (Safirova et al. 2007). As before mentioned, urbanization brings the transfer of residence area and change of lifestyle from rural to urban, and therefore causes a switch of the civil energy resource for residential use from traditional biomass fuels to more modern fuels, with greater potential for energy efficiency measures (EIA, International Energy

[24] https://www.eia.gov/totalenergy/data/monthly/dataunits.php

Outlook 2016, p.103). However, many studies found that the net total energy consumption in the residential sector has not been proved declining even though with more renewable energy resource and efficient appliances. The effects of urbanization on energy use show two opposing views: improvements in energy-related equipment (e.g., HVAC system) associated with urban lifestyle increase the efficiency indeed, but higher numbers of households resulted from urbanization and increased penetration of energy-consuming products (e.g., air conditioning at home) increase energy demand too (WANG 2010). According to the World Bank statistics, residential energy consumption nearly tripled in China in the same period with its double urbanization rate and coal is still as the main residential energy source, and thus triggering serious environmental pollution or other social risks simultaneously. However, another phenomenon was found by Darmstadter that there is a unique characteristics of residential energy use in densely-populated urban areas both in developed and developing societies. For instance, multi-family housing considered high population density allows for more energy efficient than single-family homes (Darmstadter 2004), which could be explained with the complexity of home energy using patterns and/or effects of interaction among residents.

The impacts of urbanization on residential energy consumption and therefore increasing CO_2 emissions should be discussed not only in the context of the economic and environmental area, but also in a more broadly field of research. Urbanization is a demographic indicator in the social range, which depends on the economic structure, geographic features, technological knowledge and confidence level, energy prices and the relative policies, as well as a sufficient information access etc. Therefore, for the time being, the most reasonable and effective approach to improve the residential energy efficiency is to gradually build a synthesized optimization system with the efforts of technological progress and behavioural advance, as well as shift of household energy carriers to renewable energy, which depends in turn on a continuous and healthy urbanization.

3.2 Influencing factor: Residential construction and design strategies

Housing construction has been evolved continuously from meeting the simple purpose of providing shelters in the early time to satisfy higher life requirements in the modern society at nowadays, which increase the complexity of homes, drive the use of innovative materials and promote new building technologies. The technological revolution of residential construction and design is highly required with the increased population in urban areas in particular, and challenge the building industry and architectural and engineering profession simultaneously.

Building construction has been shaped over time by variety factors and conditions, which spread over many fields, such as meteorology, demography, cultural habitat, economics and politics, related to the construction industry. As pressure grows to refrain from energy poverty and reduce CO_2 emissions, conventionally built residential structures are constantly challenged to improve indoor environmental quality without increasing demand on energy and household expenditure. Therefore, the energy efficiency issue is becoming the core challenge and pursuit of innovating residential building system, which require an interdisciplinary planning by architects and engineers for a sustainable residential building design.

The international standard ISO 13153[25] identifies the function of building designers (i.e. architects, civil and energy engineers): "*designers play the most important role in the wide propagation of energy-saving technologies because they often make the final decisions on whether energy-saving technologies should be adopted or not, and which energy-saving technologies should be adopted in actual building projects.*". According to ISO 13153, building designers can make decisions on whether energy-saving technologies are suitable for a particular building project and how these elemental technology options are put into practice at different stages of the design process based on its specific design and other conditions, like climate condition and financial feasibility etc.

In technical details, the energetic functions of architectural and engineering designs are realized by a variety of factors involving: **(1)** building orientation and layout; **(2)** building façade design (e.g., window-to-floor-area ration, glazing type, fixed exterior shading, and solar heat gain control strategies) (Zelenary et al., 2011, Carmody and Selkowitz et al., 2004, Shan 2014); **(3)** building envelope thermal insulation; **(4)** heating and ventilation system and air conditioning (HVAC); **(5)** solar panel for supplemental thermal supply. In addition, natural lighting, and architectural aesthetics, etc.

(1) Building orientation and layout

Residential building orientation and layout as well as location constitute the building morphology that is an important design parameter affecting energy efficiency of residential construction, which influence the amount of annual solar energy a residential building receives and its year-round indoor temperature and comfort, therefore further affects its energy demand for heating and cooling. In addition, it influences also the daylighting and natural ventilation level and therefore its domestic electricity demand.

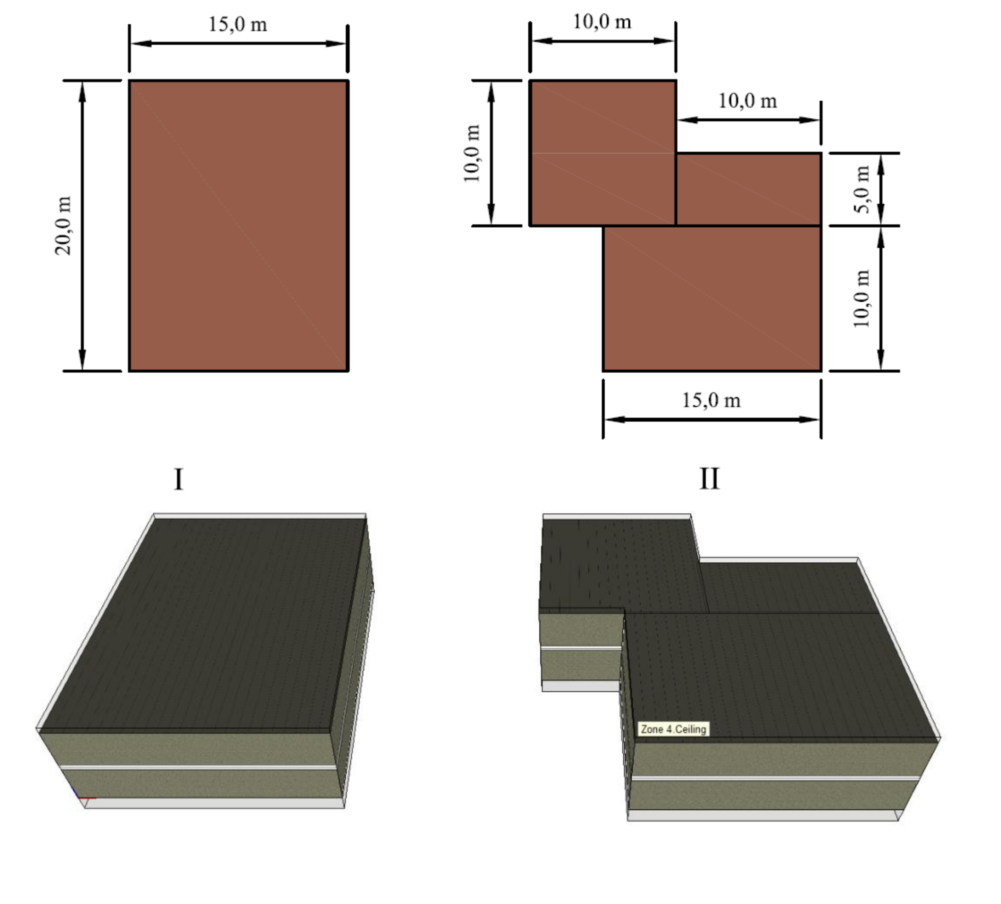
The orientation of residential building is the direction faced by its external facades. Building orientation plays an important role in optimizing the interaction between outdoor climate and indoor comfort, which embodies in two aspects: one is the heat effect of solar

[25] ISO 13153 (2012) provided the framework for a design process for single-family residential and small commercial buildings, characterized by the "energy consumption ratio" as the key criterion. (https://www.standards.govt.nz/touchstone/energy/2012/oct/iso-standard-for-designing-the-ultra-efficient-home/)

radiation on walls and windows, therefore on indoor temperature, particular for the case of indoor temperature elevation due to solar penetration through windows in summer; another is indoor ventilation affected by the relation between the direction of prevailing wind and exposure and size of openings like windows (Givoni 1994, p. 24). In summer, the direct solar radiation on external walls and windows is to be minimized under the condition of good ventilation for fresh indoor air. In winter, it has to ensure that rooms have adequate exposure to sunlight, while the attack of cold wind must be avoided. Therefore, in the consideration of thermal environment and energy conservation, the (near) “north-south direction” is normally regarded as the best housing orientation, but the “east-west direction” should be generally avoided as far as possible. If residential construction cannot be set in “north-south direction” or closed because of any limitation, it is necessary to ensure that rooms are located in the leeward or sunny position in winter. Meanwhile, it needs to pay attention to the space between residential building and the neighbouring ones or trees that shade the site, which means, it is suggested that the south wall of residential building should not be blocked by other buildings, particularly in winter. In addition, the solar heat can be stored by thermal mass, from the perspective of renewable energy using that is useful for west-facing walls to store heat for nights rather than only through solar panel on roofs. In generally, for a greatest energy efficiency, a house or residential dwelling unit shall have a simple, compact shape, and with the long axis running east to west.

Except the impact of orientation and location, the shape and layout of housing or residential dwellings affect the space heating and cooling load intensity. Residential unit with simple shape is typically more efficient than that with complex shape, as simple layout has smaller exposure area than that with irregular one, given the same floor area, therefore it reduces the external surface exposing to the outside (e.g., unnecessary solar radiation, erosion from rainfall and wind etc.). For example, as the Fig. 3.8 shown both 2-storeys residential buildings (I and II) have the same floor area and storey with height 3 m/storey, however, the building II has more exterior wall area, about 14% larger.

For residential units it is suggested the primary living areas where occupants spend more time to be located on the south side (e.g., living room, dining room), and also avoid to locate the rooms containing heat-producing appliances (e.g., kitchen) on the west side, instead on north or south side where has enough natural daylight, given a proper natural ventilation. It was also proved that a regular concrete slab has higher R-value than it of an irregular one, as Fig. 3.9 shown.



Building Nr.	I	II
Floor area (m^2)	600 m^2 (for 2 storeys)	600 m^2 (for 2 storeys)
Exterior wall area (m^2) (Storey height = 3 m)	420 m^2	480 m^2

Figure 3.8 Example of building shape and exterior surface area

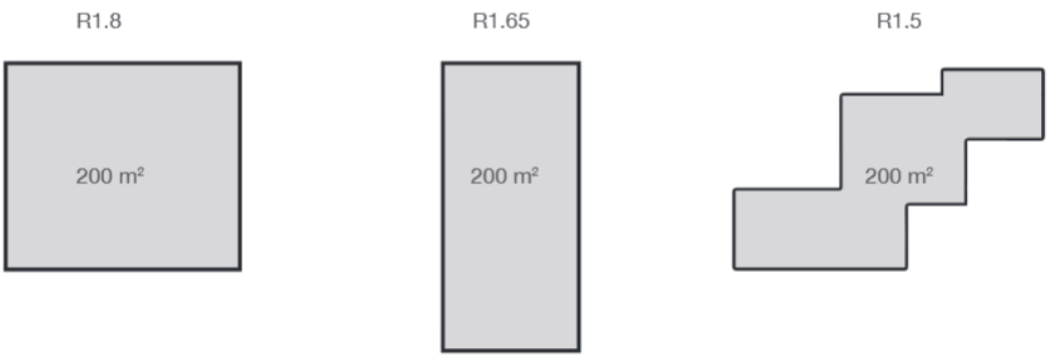


Figure 3.9 Effect of concrete slab shape on R-value (Source: Level-The Authority on sustainable building)[26]

[26] http://www.level.org.nz/passive-design/location-orientation-and-layout/

Optimal orientation and layout can contribute to reducing energy requirement for heating and cooling, and some of electricity for illumination, as well emitted greenhouse gas. Therefore, it is significantly important to consider building orientation, layout and location from the beginning of design process, as reorientation work is inconvenience and expensive for designer and occupants.

(2) Building façade design

Building façade is one of the most important aspects in terms of building energy efficiency that can be achieved through architectural efforts. Façade plays a significant role in energy consumption and the living comfort of buildings (Aksamija 2015), as building façade muss take the responsibility for protecting from risks of harsh weather and therefore ensure the indoor living requirements. The U.S. Department of Energy presented the requirements that a high-performance building façade in 2020 shall meet (DOE 2004, DOE 2001):

- **Affordable**, in terms of first cost, maintenance cost, life-cycle cost and resale vale shall be afforded by consumers.

- **Durable**, the envelope shall be durable as resistant to natural hazards and climate challenge, and offer occupants increased safety and decreased maintenance.

- **Energy-positive**, to minimize energy for heating, cooling, and lighting loads through integrated design and meet remaining loads with non-polluting energy sources, return excess electricity to the grid.

- **Environmental**, envelope shall be resource-efficient and be allowed to balance the embodies energy and durability.

- **Healthy and comfortable**, to contribute to optimize indoor air quality (e.g., better ventilation, improved thermal comfort, convenient daylighting), and protect from natural risks (e.g., fire, chemicals, and radon).

- **Intelligent**, to enable the best indoor living comfort with the least energy consumption and therefore to avoid energy waste.

As mentioned before, an energy-friendly building envelope, in particular facing west side, can be used as solar energy storage element.

The fenestration components as the most important part of building façade play a critical role in ventilation, thermal comfort or cooling energy demand, as well as in aesthetic design, which have impacts on overall building energy consumption and living comfort of occupants. In comparison to other opaque components of façade, windows have lower thermal resistance but higher transparency, which is beneficial for natural daylighting and therefore reducing electricity consumption for artificial lighting. However, it is detrimental for the excess solar gain through windows in cooling period. The largest thermal fluctuations appear always on windows where are the coldest interior surface part in winter while the warmest in summer (Aksamija 2015). Besides, it is highly noteworthy that window is a building constructional element that has the most interaction with occupants for heating, cooling, ventilation and lighting requirements. The energy efficiency of windows depends on both window size (i.e. window-to-wall ratio, WWR) and its energy properties, and is normally assessed by different design-standards compared with standards for other constructions elements, as the energy balance through windows is carried out not only through the reduction of transmission losses, but also through the gain of solar energy that depends on the windows orientation and geometry, glazing system and glass types (Martin 2007, p.25).

The window-to-wall ratio is the ratio of the window area to the gross wall area[27] for a building façade. The WWR reflects the total area of windows. Precisely as two sides of the same coin, a high window-to-wall ratio allow more natural lighting into interior space, but Yang et al.in their study under different climate conditions, proved that the total energy consumption increased when the WWR is also increased (Yang et al. 2015). Kim et al. also in their research suggested that the annual energy load increases as the window size increases, nearly independent on the position of window on façade, because a very small difference occurred only as WWR under 20% (Kim et al. 2016). Energy properties of windows depend mainly on the heat transfer coefficient (U-value) of glass and frame, the solar heat gain coefficient (SHGC), the visible transmittance (VT[28]), and the shading factor of shading device (Nasrollahi 2013). Therefore, an ideal window shall provide comfort lighting levels without glare and high thermal insulation level to reduce indoor energy loss through glass and frame, as one of energy efficient parts of lighting system and building climate control. In terms of shading devices (interior and exterior), the main advantage is to adapt to solar transmission during days and seasons through adjusting shading devices. Exterior shadings are more effective than interior shadings in reducing solar heat transmission through windows or any transparent components of buildings, and light-coloured shadings are better than dark ones, because they can reflect more and absorb less radiation[29]. Since a few years, some advanced shading technologies have been developed as integrated solutions for controlling natural light and solar heat gain. A combination between shading control device and daylighting control system contributes to

[27] The gross wall area is the sum of window area and wall surface on a single façade.

[28] Visible Transmittance: the amount of light in the visible portion of the spectrum that passes through a glazing material. (http://www.commercialwindows.org/vt.php)

[29] http://www.teriin.org/ResUpdate/reep/ch_3.pdf

reduce the electricity loads for room lighting and also address the visual comfort for occupants[30].

Building façade plays a significant role in thermal load control, air infiltration and exfiltration, ventilation, moisture control, and ensuring audible and visual comfort, disaster-resistant, utilization of renewable energy, as well as living privacy and building aesthetics.

(3) Thermal insulation of building envelope

Energy consumption for residential heating and cooling is influenced to a large extent by the building insulation level, in particular of the building envelope (e.g., external walls, roof, windows and frames), as well as basement and ceiling. A proper insulation could reduce heat loss in cold weather, particularly where heat supply is the main energy demand, such as Germany, North China, as well prevent heat wave in hot weather like South China.

As a part of building structures, envelope forms the primary thermal barriers between interior and exterior. The thermal performance of envelope is described as an ability of a building structure to absorb, conserve and release heat when the ambient temperature rises and falls, which plays a key role in determining levels of living comfort, and heating/cooling energy demand (IEA 2013, p.5). The thermal envelopes of buildings are designed differently due to various local climate conditions. The insulation level of an envelope is normally measured by the thermal transmittance, also known as U-value. U-value $[W/(m^2 \cdot K)]$ is the heat transfer coefficient and describes how well a building conducts heat or the rate of transfer heat (which can be s a single material or a composite) through one square meter of a structure divided by the difference in temperature across the structure, which is standardized in EN ISO 7345[31]. It depends on thermal characteristics of building materials (i.e. λ, thermal conductivity) and thickness of structure elements, as Equation 3-1 describes. Advanced building envelope design can reduce the energy consumption for heating and cooling by up to 60% (Winbuild 2012).

$$U = 1/R_T = 1/[R_{si} + d_1/\lambda_1 + d_2/\lambda_2 + \ldots d_n/\lambda_n + R_{se}] \qquad [W/(m^2 \cdot K)] \qquad (3\text{-}1)$$

where,

$$R_T = d/\lambda = R_{si} + d_1/\lambda_1 + d_2/\lambda_2 + \ldots d_n/\lambda_n + R_{se} \qquad [m^2 \cdot K/W]$$

λ: thermal conductivity of building materials $[W/(m \cdot K)]$

[30] http://www.commercialwindows.org/shading.php

[31] DIN EN ISO 7345 (January 1996): Thermal insulation – Physical quantities and definitions.

Traditionally built residential buildings are high thermal mass structure, because the main traditional building materials are concrete, stone or masonry, for ensuring the necessary requirement on insulating performance. However, these traditional building materials have relevant higher U-values (e.g. the U-value of 25 cm thickness concrete wall is 3.3 W/(m^2•K), 24 cm thickness clay brick is about 1.5 W/(m^2•K)), which means, in spite of good heat conductors they do little to avoid heat loss through heat transfer from interior to exterior. Besides, most of those traditional structures have high wall thickness and suffer thermal bridges that are most often caused by improper installation or building design, or by unsuitable material choice. Therefore, most traditional building envelopes fall short of meeting both practical and artistic needs of modern residential buildings, particularly in densely populated urban areas.

Since a few decades various insulation concepts have been developed to respond to housing thermal needs suited in different climate zones. Regarding insulated position of housing the typical insulations are located in interior or exterior walls, roof or top floor ceiling, basement ceiling or basement exterior (if necessary), glazed surfaces, heating system and heat storage unit (e.g., pipes). Table 3.1 lists the typical thermal insulated building materials and their thermal conductivity λ [W/(m·K)].

Table 3.1 Thermal conductivity λ and application of commonly used building insulation materials

Building Insulation materials	**λ [W/(m·K)]**	**Application**
Vacuum Insulated Panel (VIP)	0.004-0.008	Façade
Expandable polystyrene (EPS)	0.020-0.040	Roof, wand, ceiling, floor, footstep sound insulation, and basement
Polystyrene extruder foam (XPS)	0.020-0.040	Flat roof (e.g. inverted roof, green roof, terrace, park decks), floors (load-bearing), and basement
Glass fibers	0.038-0.050	Entire façade, targeted light opening
Mineral wool (glass wool, stone wool)	0.035-0.050	Sloping roof, flat roof, façade, partition wall, insulation of internal space, footstep sound insulation
Polyurethane rigid foam (PUR)	0.027-0.029	Flat roof, floor, basement, exterior walls, interior insulation
Wood fiber, wood shavings, cork	0.040-0.070	Walls, roof, floor, and interior insulation

One of envelope insulation measures is to reduce or avoid thermal bridges. DIN EN ISO 10211[32] defines the thermal bridge, which is part of a building envelope where the uniform thermal resistance is significantly changed by

- a complete or partial change of building materials with different thermal conductivity, and/or
- a change in the thickness of envelope components, and/or
- different size between inner and outer surface, such as on wall-, floor-, and ceiling connections.

and where more heat losses than the surrounding area, resulting in a „short circuit“ insulation[33], Fig. 3.10 depicts the common positions on building construction where occur thermal bridge.

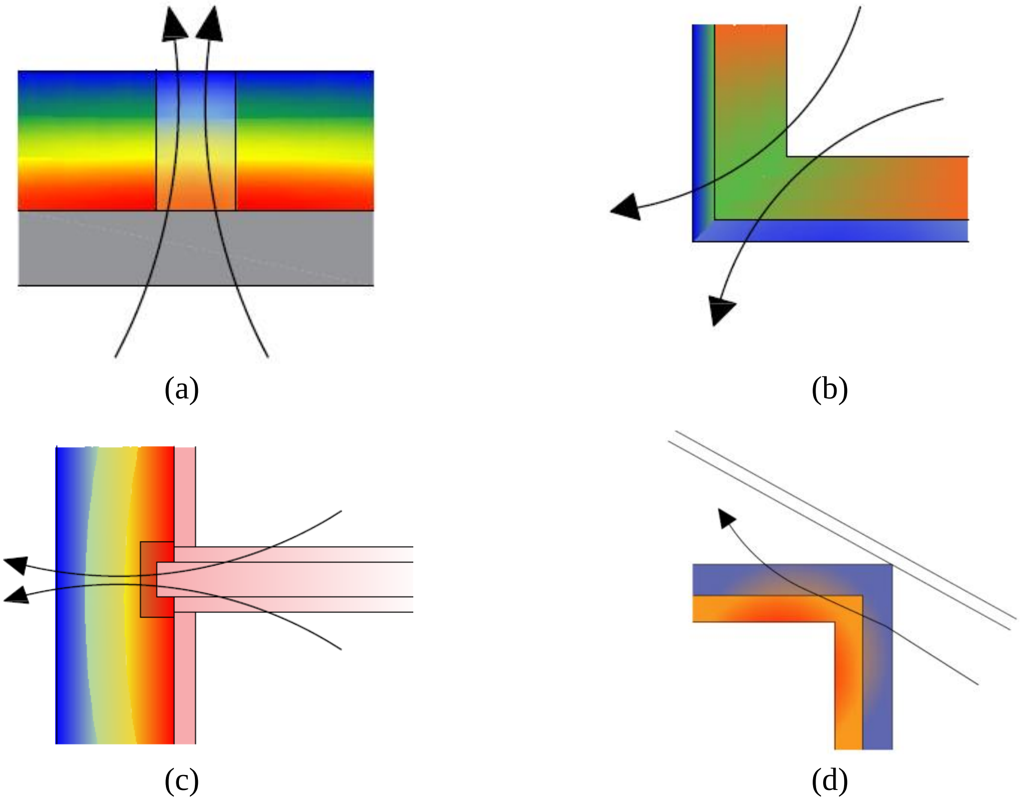


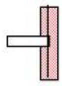
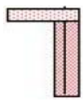
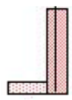
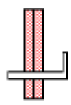
Figure 3.10 Schematics of thermal bridges in building structure

[32] DIN EN ISO 10211 (April 2008): Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations (ISO 10211:2007).

[33] http://ncma-br.org/pdfs/66/TEK%2006-13B1.pdf

As Fig. 3.10 shown: (a) Material difference resulted thermal bridges; (b) Geometrical thermal bridges, e.g. building corners; (c) Structural thermal bridges on junction between different components, e.g. openings in walls for windows and doors, joints where beams and slabs through envelope; (d) Connective thermal bridges, e.g. the outside air penetrates into the attic (Olsen and Radisch 2002), or structure component with badly installed insulation. With regard to construction components specifically, the common positions of thermal bridges that result in energy loss due to leaking through them are listed in Table 3.2.

Table 3.2 Thermal bridges of building construction elements

Position	Legend*
External wall/internal slab	
External wall/internal wall	
External wall/external wall	
External windows perimeter	
External doors perimeter	
Roof/external walls	
External slab/external walls	
Balcony floor/external walls	

External slab/internal walls	
Roof/internal walls	
Others (e.g., floor slab of basement, entrance door)	

*source: EQUA Simulation Institution

Thermal bridges include three different types based on the positions, i.e. area thermal bridge, linear thermal bridge, and point thermal bridge. DIN V 18599-2[34] identifies the transmission heat coefficient in details, and DIN EN ISO 14683[35] formulates the transmission heat losses as equation (3-2) that describes the building heat losses owing to thermal bridges of all encounter building structure components, taking all three types into account,

$$H_D = \sum_i A_i \cdot U_i + \sum_k l_k \cdot \psi_k + \sum_j \chi_j \qquad (3\text{-}2)$$

where,

H_D: the transmission heat losses

A_i: area of the building components i of building envelope, in m^2

U_i: thermal transmission coefficient of building components i of building envelope, in $W/(m^2 \cdot K)$

l_k: length of the linear thermal bridge k, in m

ψ_k: thermal transmission coefficient of the linear thermal bridge k, in $W/(m \cdot K)$

χ_j: thermal transmittance of the point thermal bridge *j*, in W/K

[34] DIN V 18599-2 (October 2016): Energy efficiency of buildings - Calculation of the net, final and primary energy demand for heating, cooling, ventilation, domestic hot water and lighting - Part 2: Net energy demand for heating and cooling of building zones.

[35] DIN EN ISO 14683 (April 2008): Thermal bridges in building construction - Linea thermal transmittance - Simplified methods and default values (ISO 14683:2007).

Avoiding thermal bridges as far as possible contributes not only to saving of energy and costs, also to increasing the lifetime of buildings, for example, moisture reduction, condensation control. An effective concept to avoid thermal bridges includes both structural thermal optimization (e.g., a continuous insulation of building envelope) and high-insulated building materials. Passive House concept builds thermal bridge-free construction with taking the three type thermal bridges full into account, and through the relative conservative rather than optimistic calculation methods in Passive House Planning Package (PHPP)[36], this design concept ensures a zero thermal bridge building construction.

Though all building designs have a common goal, to save energy and improve indoor environmental quality, different countries or regions have own specifically building standards and requirements. The following part introduces the different characteristics of residential building design of Germany, China, and the U.S., particularly with regards to thermal insulation.

Germany

In Germany, up to 40% of the annual heating energy consumption is lost through the building envelope, i.e. the exterior walls. Higher insulated materials and the thermal insulation composite systems are developed for wall, roof and façade insulation, as well as attic and basement ceiling, which aim for the good of insulation performance on one hand, on the other hand for reduction of building weight. Relevant regulations set the maximum annual primary energy demand and the maximum permissible values of the specific transmission heat loss H_T [W/(m^2•K)] for residential buildings, which are mainly relative to the insulation of building envelope areas and calculated according to EnEV. The basic requirements on the thermal performance of residential buildings (i.e. U-values of envelope elements, max. annual primary energy demand) are defined in EnEV 2014[37], as Table 3.3 and 3.4 below describe.

Table 3.3 Requirements on heat performance of reference residential building

Nr.	Building components/Systems	Reference value (Unit)	
1.1	Exterior wall (including fixtures, such as roller shutters), floor covering against outside air	Thermal transmittance value (U-value)	U = 0.28 W/(m^2·K)
1.2	Exterior wall against		

36 http://passivehouse.com/04_phpp/04_phpp.htm

37 EnEV 2014 - Anlage 1 (zu den §§ 3 und 9) - Anforderungen an Wohngebäude.

	ground, floor slab, walls and ceilings of unheated rooms	Thermal transmittance value (U-value)	U = 0.35 W/(m^2·K)
1.3	Roof, top floor, side-walls	Thermal transmittance value (U-value)	U = 0.20 W/(m^2·K)
1.4	Windows, French doors	Thermal transmittance value (U-value)	Uw = 1.30 W/(m^2·K)
		Overall energy transmittance of glazing	$g_\perp$ = 0.60
1.5	Roof windows	Thermal transmittance value (U-value)	Uw = 1.40 W/(m^2·K)
		Overall energy transmittance of glazing	$g_\perp$ = 0.60
1.6	Domed roof light	Thermal transmittance value (U-value)	Uw = 2.70 W/(m^2·K)
		Overall energy transmittance of glazing	$g_\perp$ = 0.64
1.7	Exterior doors	Thermal transmittance value (U-value)	U = 1.80 W/(m^2·K)
2	Building components referring to Nr. 1.1 - 1.7	Standard thermal bridge value (according to DIN 4108 and EnEV 2002/2004)	ΔU_{WB} = 0.05 W/(m^2·K)
3	Air tightness of building envelope	Measurement value of air flow rate n_{50}, (i.e. $ACH_{50} = Q_{50}$•$60/V_{Building}$, with Q_{50} is the airflow at 50 pascal [m^3/minute] and $V_{Building}$ is building volume [m^3])	Calculated according to: • DIN V 4108-6: with tightness test • DIN V 18599-2[38]: category I
4	Sun protection device	Not sun-protection demand within the framework of reference building	
5	Heating system	• Heat generation by condensing boiler (improved), heating oil. Installed: - for buildings up to 500 m^2 gross internal floor area within the thermal envelope - for buildings with more than 500 m^2 gross internal floor area outside of the thermal envelope	

[38] DIN V 18599 (February 2007): Energy efficiency of buildings - Calculation of the net, final and primary energy demand for heating, cooling, ventilation, domestic hot water and lighting - Part 2: Net energy demand for heating and cooling of building zones.

		• Design temperature 55/45 °C, central distribution system within the heat transferring area, internal strands and connecting lines, standard length of cable according to DIN EN 4710-10[39], in Table 5.3-2, pump equipped on demand, hydraulically adjusted pipe network • Heat transfer with static heating surfaces, arrayed to the normal outer walls, thermostatic valves with proportional range of 1 K
6	Water heating system	• Central water heating system • Joint heating supply with heating system above • Distribution system within the heat transferring enclosure area, internal strands, installation wall in common, standard length of cable according to DIN V 4710-10 Table 5.1-2 with circulation • Installation of solar system with flat collector for exclusive drink water heating
7	Cooling	No cooling demand
8	Ventilation	Central exhaust air system, demand-based regulated DC-ventilator
Remark: The annual primary energy of the reference building calculated according to the requirements 1.1 - 8 above shall be multiplied by 0.75 for new residential construction projects since 1st January 2016.		

(Source: EnEV 2014: Anlage 1 (zu den §§ 3 und 9) - Anforderungen an Wohngebäude)

Table 3.4 Maximum specific heat transfer area related heat loss

Nr.	Building type		Maximum specific transmission heat loss
1	Detached house or residential building	A_N [40] $\leq 350\ m^2$	$H_T = 0.40\ W/(m^2 \cdot K)$
		$A_N \geq 350\ m^2$	$H_T = 0.50\ W/(m^2 \cdot K)$

[39] DIN EN 4710-10 (2003-08): Energy efficiency of heating and ventilation systems in buildings - Part 10: Heating, domestic hot water supply, ventilation. (new vision was issued in May 2016)

[40] A_N: the usable floor area of building, which is used in Germany as an energy reference surface area for residential buildings in connection with the German Energy Saving Ordinance (EnEV). $A_N = V_e \cdot 0.32/m$, V_e is the heated building volume and is calculated based on the heat transferring surrounding arear A (determined in accordance with EnEV 2009, Annex 1 No. 1.3.1) and space ceiling height.

2	One-side detached house or residential building[41]	$H_T = 0.45\ W/(m^2 \cdot K)$
3	All other types of house or residential building	$H_T = 0.65\ W/(m^2 \cdot K)$
4	Reconstruction and extension of residential buildings according to EnEV 2014 § 9, paragraph 5	$H_T = 0.65\ W/(m^2 \cdot K)$

(Source: EnEV 2014: Anlage 1 (zu den §§ 3 und 9) - Anforderungen an Wohngebäude)

The thermal insulation panels made of Styrofoam (e.g., expanded polystyrene EPS and extruded polystyrene XPS)[42] (Lindemann) as Figure 3.11 shown, glass fiber and rock wool as Figure 3.12 shown, are normally used as insulation walls. These substances are heat-insulated effective because the interstices inside them contain air that has relatively high heat capacity.

Figure 3.11 Expandable polystyrene (EPS) as insulation material for extern walls[43]

Double or triple glazed windows or insulated windows are used to reduce heat loss through the windows. The roof is often insulated with mats of glass wool with a high cubic content of air, and the insulation mats are normally lined inside. Meanwhile, it prefers to exterior insulation because insulation of exterior walls does not take up part of the living area and thus ensure enough inside living space.

41 One-side detached house or residential building refers to a house or residential building that a proportion of 80% or more of the building vertical areas, which point towards a heaven direction, adjoins another residential building.

42 http://www.waermedaemmstoffe.com/htm/polystyrol.htm
https://www.buildings.com/article-details/articleid/8498/title/insulation-eps-and-xps

43 Photos: Fachverband WDVS (left); Hessisches Ministerium für Umwelt, Energie, Landwirtschaft und Verbraucherschutz(right), https://www.energiesparaktion.de/downloads/Downloadbereich/energiespa-rinfo/espi2.pdf

Figure 3.12 Insulation materials: Glass fibres (left) and Rock wool (right)[44]

China

Building energy use in China accounts for about one-third of final energy consumption. Residential subsector dominates the main part of building energy consumption with roughly 74% of the total energy consumed in building sector (IEA & Tsinghua University 2015, p.31). Space conditioning is the largest energy end-use in building sector, i.e. space heating in cold zone referring mainly to the Northern cities, space cooling in the hot zone referring mainly to the Southern cities, and both for moderate climate zone.

Most new residential buildings in China are insulated in accordance with the design requirement, however, the majority of residential buildings are still under-insulated. Relative weak building insulation results in much more energy consumed for space heating and cooling than buildings in developed countries with similar climate and construction conditions, thus leads not only to more energy consumption and expenditure, but also causes severe air pollution that is a major public health concern of the Chinese government, because coal is still the main fuel for space heating in China with coal boiler and co-generation (mostly coal-driven) for heating energy supply.

Though the Chinese construction industry and building developers gave the substantial efforts on new residential construction over the past decades that strictly comply with design criteria and pay more attention on energy efficiency, retrofitting of existing residential buildings has been continuously processed according to the mandatory standards and local financial capacity, and undertaken in different scales. With regard to energy efficiency retrofit it refers to generally the following proposals that combined with envelope retrofits (Shui and Li 2012, p.47):

- Comprehensive retrofit: building envelope, windows, indoor heating metering, and outdoor heat system

[44] Photos: www.baunetzwissen.de

- Building envelope only
- Windows only
- Building envelope, indoor heating system and metering
- Building envelope and outdoor heating system
- Building envelope and geothermal pump

The main task of retrofitting is still to improve the insulation, particular the insulation of external/internal walls. Therefore, since recent decades many high-insulates materials were widely used for building construction.

In China the synthetic insulation materials are dominant because of its better thermal properties and lower price compared to mineral thermal insulation materials, however, mineral insulation materials are higher fireproof than synthetic materials (Yu et al. 2014). Rock wool is increasingly used for insulation of external walls, as Fig. 3.13 shown. Glass fibers are normally used for ceiling insulation, as Fig. 3.14 shown. The asbestos insulation layer commonly used in the past has been gradually prohibited or replaced by other environment and harmless insulation materials.

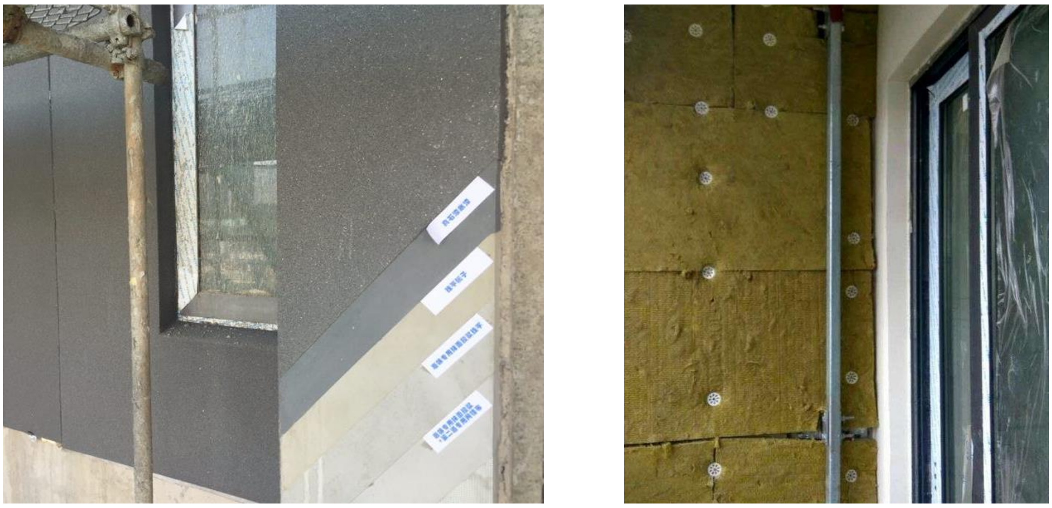


Figure 3.13 Insulation material: Rock wool, test piece (left) and insulation of external wall on site (right), Photos taken by self

Figure 3.14 Roof insulation with glass wool on site

USA

In the USA, “Superinsulation” has been developed and used for most buildings since the 1970s, which is an approach to design, construction and retrofitting that dramatically reduced heat losses in winter and heat gains in summer by using much higher levels of insulation and airtightness than normal standards. Though there is no universally agreed definition of the “Superinsulation”, the super-insulated built units have to abide by the necessary requirements, for example, very high levels of insulation such as typically R-40 (RSI[45]-7) walls (U-value of 0.15 W/($m^2 \cdot K$)) and R-60 (RSI-10.6) roof (U-value of 0.1 W/($m^2 \cdot K$)), a continuous insulation to reduce thermal bridge as far as possible, no large windows facing any particular direction, a heat recovery ventilation system to provide fresh air, as well heat system is much smaller than conventional ones, sometimes just a small backup heater and so on. Nisson and Dutt have suggested that a house might be described as “super-insulated” if the cost of space heating is lower than the cost of water heating (Nisson and Dutt 1985).

Various types of insulation material are chosen for different residential building components. For instance, the most common and widely available type of insulation is the blanket insulation, which comes in the form of batts or rolls making of flexible fibers (e.g. fiberglass, rock wool, slag wool, plastic fibers, natural fibers, cotton and sheep’s wool etc.), and is normally used on unfinished walls including foundation walls, floors and ceilings[46]. For some hard-to-reach places or irregularly shaped areas of residential buildings, it is suggested to add or optimize insulation by the way of loose-fill and blown-in, with insulation materials like cellulose, fiberglass, and mineral wool. In addition, concrete block insulation is popular for new construction or major renovations, foam board or rigid foam for floors and ceilings, and insulation concrete forms for foundation walls of new

[45] Thermal resistance value R is sometimes denoted RSI-value if the SI (metric) units are used. R and RSI value converter: https://www.isolofoam.com/english/r-and-rsi-value-converter

[46] https://energy.gov/energysaver/types-insulation

construction, etc. The insulation types depend on the construction condition and occupants' requirements to some extent. The U.S. Department of Energy (DOE) provides many kinds of insulation types to consumers for retrofitting existing houses or building new ones. The International Energy Conservation Code (IECC) provides the relevant insulation materials and thickness for different building types (e.g., high-rise apartment, commercial buildings, schools, hospitals, warehouse etc.) in different geographic locations (i.e. under different weather and climate conditions). Due to a great difference of climate status among different locations in the U.S., the requirements on building insulation vary significantly, therefore the choice of insulation materials and construction shall take the local climate and weather conditions into account. The most common insulation materials consist of fiberglass, rock, cellulose (a fibre insulation material), natural fiber (e.g., cotton, straw, and sheep's wool) and rigid foam boards etc., as Fig. 3.15 shows.

Figure 3.15 Left [47]: Cellulose insulation (photo from: Cellulose Insulation Manufactures Association); right [48]: Icynene plastic insulation (photo by Paul Norton, NREL)

A general characteristic of all these insulation materials is pursued with relative high R-value. Meanwhile, Department of Energy U.S. (DOE) regulates the insulated location of residential building or housing, from external/internal walls, floors, foundation, attic and ceiling, basement, and crawlspace to duct insulation, as Fig.3.16 shows. The unfinished attic spaces (1), attic access door (1A), in finished attic spaces with or without dormer including between the studs of knee wall (2A), between the studs and rafters of exterior walls (2B) and roof (2B), celling with cold spaces above (2C), extend insulation into joist space to reduce air flows (2D). For exterior walls (3), insulation points consist of walls between the heated living space and unheated spaces like garages (3A), and foundation walls above ground level (3B) and in heated basements (3C). All floor parts above cold

[47] https://energy.gov/energysaver/weatherize/insulation/insulation-materials

[48] https://energy.gov/energysaver/weatherize/insulation/types-insulation

spaces have to be insulated too (4A-4D); and also the insulation of band joist[49] (5). Particularly in the cold climates, it has to ensure the insulation of storm windows that are mostly intended to improve the insulation of existing windows, especially single-glazed units[50]. In addition, the joists points and windows and window frames are required to be insulated for ensuring efficient heating and cooling too.

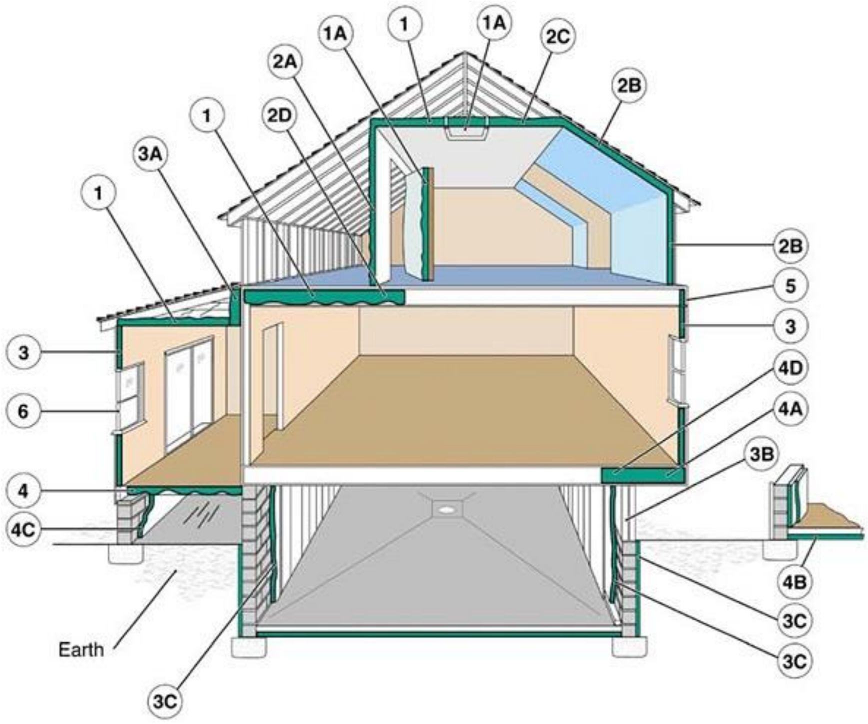


Figure 3.16 Housing insulation in USA (source: Oak Ridge National Laboratory[51])

The thermal performance of a whole building is influenced by the all involved components, which are defined by the thermal conductivity of materials, the solar transmittance of window glasses, as well as the construction attributes, e.g., wall thickness, number of glass panes, and area of envelope etc.

Although the higher performance of heating distribution devices and system equipped in building or each dwelling (e.g., radiators and convectors, thermostats) are able to optimize the indoor thermal comfort, it does not provide any comparative advantage in buildings with high thermal efficiency. Therefore, it is usually more valuable to optimize the thermal conductivity of the envelope including particularly façade, roof, windows and window frames (Schulze-Darup 2009). In other words, airtightness of residential building is critical to reduce heating energy consumption.

[49] https://www.energydepot.com/RPUcom/library/BUILD004.asp

[50] https://energy.gov/energysaver/storm-windows

[51] https://energy.gov/energysaver/where-insulate-home

(4) Heating, ventilation and air conditioning (HVAC)

Heating, ventilation, and air conditioning systems control the indoor temperature, humidity, and air quality to meet the occupants' requirements under a set of exterior conditions. Energy consumption for HVAC systems are affected by different factors, for example:

- The design and operation of building, which influences how the external environment affects the internal environment.

- The design and installation of HVAC systems, which ensure an effective and efficient indoor temperature and humidity control.

- The operating efficiency and average work time of HVAC equipment, which affects energy demand for operation of HVAC system.

- The internal heat gains by lighting, electrical appliances and occupants, which affects the real indoor temperature and thus the heating/cooling demand.

- Individual requirements on indoor temperature and humidity by different occupants, especially for occupants in residential buildings.

As above (1) and (2) mentioned, building design, layout and orientation affect solar energy and natural lighting obtain to a great degree, therefore resulting in different indoor air temperature and energy demand for heating, cooling, ventilation. However, improper design and installation of HVAC systems cause an unwanted high household energy costs and a significant degrading of living comfort. Therefore there are some key factors that shall be considered for obtaining an efficient HVAC system:

- Sizing the system targeting the specific heating and cooling load of a home being built (e.g., avoiding oversized equipment), some energy efficient or passive solar homes require less heating and cooling energy.

- Different minimum-ventilation is required by different space-use types and occupant densities (DOE 2015[52]). Sizing the ventilation scales according to the real ventilating need where natural ventilation is not enough to meet. Increased ventilation increases energy consumption when unconditioned.

- Sizing and designing the layout of ductwork or piping for maximal energy efficiency of the systems.

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[52] Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities - Chapter 5: Increasing Efficicency of Building Systems and Technologies. DOE, September 2015.

- Good insulation and sealing of pipe and ductwork.

- Proper selection and installation control.

- Programmable thermostats, which can adjust the indoor temperature based on occupancy and occupants‘ indoor activities automatically.

- In addition, changing occupant behaviour on HVAC systems, and regularly maintaining existing systems[53].

(5) Air tightness

An efficient performance of HVAC systems cannot be guaranteed without an air-tight building construction. The air-tightness of a building is commonly determined by the Air Change Rate (ACR) or Air Change per Hour (ACH), which provide a principle air change requirement under the condition of proper performance of ventilation system. A building shall be sealed as tightly as possible under the condition of necessary ventilation for ensuring the air quality, as a well air-sealed building can reduce heating, cooling and ventilation energy consumption by as much as 30%. According to research by IEA, most buildings worldwide have been well air-sealed except some northern European countries and North America. According to VDI (2001) 4300-7[54], ACR is calculated with Equation (3-3):

$$ACR(t) = q(t)/V \qquad [h^{-1}] \qquad (3\text{-}3)$$

where,

ACR/ACH:	air change rate/air change per hour	$[h^{-1}]$
q:	air supply into a zone (i.e. a room or space)	$[m^3/h, ft^3/h]$
V:	volume of the zone (i.e. a room or space)	$[m^3, ft^3]$
t:	time	[h]

53 https://www.carbontrust.com/media/7403/ctv046_heating_ventilation_and_air_conditioning.pdf

54 VDI 4300-7 (2001): Indoor air pollution measurement – Measurement of the indoor air change rate.

DIN 1946-6[55] provides the suggested ACR of residential spaces, which is calculated depended on the total exhaust air flow of each room and usable living area, and differentiates among various residential space structure (e.g., with/without windows), natural ventilation or combined with mechanical ventilation, or high/low thermal insulation requirement. DIN 4108-2[56] provides the minimum ACR for the health of occupants and for sanitation and restriction of room moisture, i.e. ACR_{min}[57]= 0.5 h^{-1}.

Ventilation and air infiltration are important factors with respect to energy use, as in high thermally efficient buildings the both factors work as the dominant thermal loss mechanisms (Liddament and Orme 1998). Most residential units pursue effective air ventilation in both natural and mechanical manner. Natural ventilation is very popular in regions with moderate climate or heating energy as dominant energy concerns, such as Germany and most of the Nordic countries. The residential units there rely mainly on air infiltration through leakage of building envelope and operable openings (e.g., windows and doors) to ensure the necessary air change.

Natural ventilation is affected largely by the window-wall-rate and opening arrangement, the climate factors (e.g., wind direction and speed) and thus resulting air pressure difference between indoor and outdoor environment. Meanwhile, occupancy and occupant behaviour have significant impacts on the frequency of natural ventilation. Therefore comparing with natural ventilation, mechanical ventilation system provides high uniform ventilation rates (Hekmat et al. 1986), but which needs additional energy to operate the system. Especially for some regions in hot summer, a mechanical ventilation system is always necessary for each household, such as in most cities of Southern China, to ensure a comfortable indoor temperature, meanwhile to reduce the unexpected indoor humidity effectively.

Both natural and mechanical ventilation systems influence indoor air quality in different manners with individual advantage and disadvantage. The natural ventilation system has no extra construction costs and obvious operating costs, but which is suffering poor or inefficient control over ventilation rates (Russell et al. 2005, p.14). In contrast, mechanical ventilation system has to be achieved at a certain additional cost, but it is able to ensure more stable ventilation rate even with leaky building envelope. For those reasons, a rational combination of natural and mechanical residential building ventilation is vital to achieve a cost-effective ventilation process without a compromise of indoor air quality.

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[55] DIN 1946-6 (May 2009): Ventilation and air conditioning – Part 6: Ventilation for residential buildings – General requirements, requirements for measuring, performance and labelling, delivery/acceptance (certification) and maintenance.

[56] DIN 4108-2 (February 2013): Thermal protection and energy economy in buildings – Part 2: Minimum requirements to thermal insulation.

[57] ACR_{min} = 0,5 h^{-1} means full air change occurs each 2 hours

Schulze-Darup found out in his research that in a highly thermal-insulated building with a heating load below 10 W/m^2 an efficient and user-convenient heat distribution and provision could be achieved via ventilation system successfully (Schulze-Darup 2009).

From the perspective of energy saving, heat recovery ventilation system can recover the heat from the exhausted air and apply to the supply air by a heat exchanger. A typical ventilation system in buildings consists of a core unit, channels for fresh and exhaust air, and blower fans. Its work performance depends on the climate conditions, seasons and building requirement, which can basically recover up to 95% of the heat in exhaust air and therefore reduce the heat loads in winter and cooling loads in summer dramatically. It is very important that the airflows are not mixed in the process so that the indoor air quality will not be polluted.

From the perspective of sanitation of living space and health of occupants, high ACR is required, but from the perspective of energy saving, a relatively low air flow should be kept as far as possible. Therefore, a building should be constructed for ensuring both airtight and windproof under an efficient ventilation support. With the high efficient building technology so many improvements have been made to optimize building insulation and air sealing, as well as the increasing requirement on privacy of occupants that a proper air exchange could not be ensured with merely natural ventilation through doors and windows. Mechanical ventilation has to be taken into account for a sufficient air movement, not only contributing to the good of health of occupants, but also to keeping the fabric and furniture and electric appliances free from excessive moisture and subsequent decay. For instance, a mechanical ventilation system is strongly recommended for the passive house built with higher insulation standard than traditional residential building. Mechanical ventilation system supplies exactly as much fresh air as is needed for high indoor air quality and only outdoor air will be supplied rather than recirculated air.

Regulations for building ventilation performance vary among countries due to different climate conditions and building technologies. There are some different ventilation standards that introduce the recommended air change rate of residential spaces (e.g. living room, bedroom, bathroom, kitchen, laundry and basement), for example, DIN1946-6 and Passivhausinstitut-Standard in Germany, Komfortlüftung.at in Austria, and ASHRAE Standard 62.1[58] - Ventilation for Acceptable Indoor Air Quality in the U.S. etc. In addition, it has to consider different climate conditions and individual ventilation requirements, when identifying an efficient and comfortable air flow rate, in particular for a residential building where the main ventilating activities depend on the living style of occupants and the individual consciousness and perception of the indoor air quality. DIN

[58] ANSI/ASHRAE Standard 62.1 (2016): Ventilation for Acceptable Indoor Air Quality.

4108-6[59] specify typical values for the tightness of residential buildings, as listed in Table 3.5, which gives the air flow rate based on the indoor air volume of buildings where a constant pressure difference of 50 Pa between interior and exterior air has to be maintained (VDI 4300-7, 2001):

Table 3.5 Typical values for ACR $_{n50}$ for the tightness of residential buildings (DIN 4108-6)

Tightness of the building envelope	Air change rate at 50 Pa (*n50*), [h^{-1}]	
	Multiple family dwellings	Single-family house
high	0.5 – 2.0	1.0 – 3.0
medium	2.0 – 4.0	3.0 – 8.0
low	4.0 - 10	8.0 - 20

(6) Integration of renewable energy

- Solar panels

Solar energy is an effective and clean energy substitution for fossil fuels and makes a significant contribution to the reduction of energy consumption and pollutant emissions. It is sensible and economically reasonable to combine the common energy efficient measures (e.g. envelope insulation, proper ventilation) and solar system for energy consumption in residential buildings, since it particularly contributes to an investment of energy supply for domestic use and reduces energy dependence of households on fossil fuels in the long run. Except as a renewable energy generator for heating energy supply in winter, the solar panels can be also used as shading in summer.

Currently, solar energy in the field of residential application is mainly for space heating and domestic hot water supply with the solar thermal systems (STS), which are normally installed on the roof and convert solar radiation into heat for raising the temperature of heat carriers (e.g. air, water or other specially designed fluids). Depending on recent technological levels, domestic hot water for single- and multi-family houses can be prepared between 40-80% with typical solar fractions, which also can meet 15-50% of space heating demand. Efficient solar energy utilization depends on many factors except the COP of STS, like average annual sunshine, building orientation and rooftop type and direction. These factors affect the choice of the scale and installation positions of solar panels.

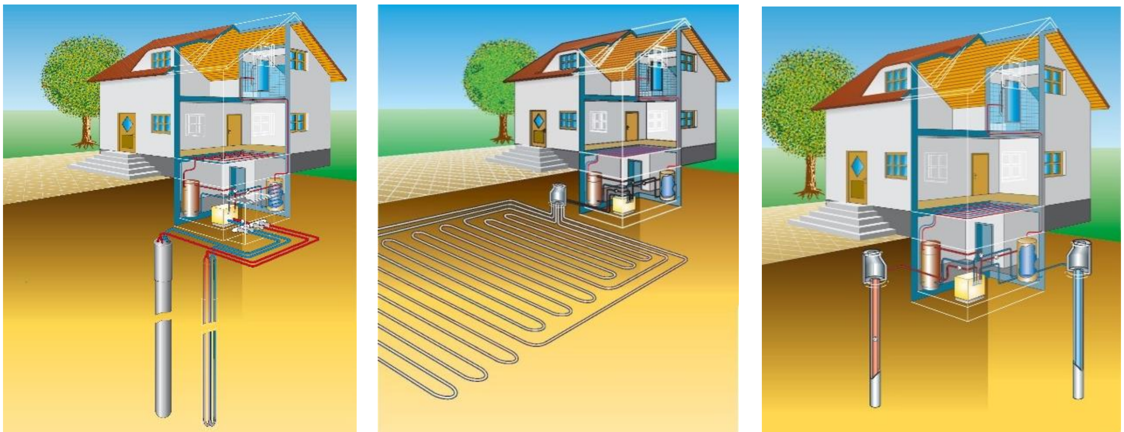
Active Solar Buildings have already been developed and demonstrated in Central European climates for both detached houses and multi-family buildings, which need a high

[59] DIN 4108-6 (2003): Thermal protection and energy economy in buildings – Part 6: Calculation of annual heat and annual energy use.

standard building insulation and enough space for solar energy collection and storage, which is now the key technological challenge (Sanner et al. 2011, p.17).

- Ground source heat pump (GSHP)

Temperature of the ground is highly constant, which provides an advantage of utilisation for heating energy supply in winter and heating energy storage in summer. Ground source heat pump (GSHP) or geothermal heat pump system has been proved as an efficient energy supply system with renewable energy source since a long history, to reduce energy consumption in homes and abate CO_2 emissions significantly with high efficiency (Bose et al. 2002, Sarbu and Sebarchievici 2010, Luo et al. 2013). GSHP systems utilize solar energy and renewable energy stored in the ground under the near surfaces for heating, cooling and hot water supplying. There are three popular heat pump types for using shallow geothermal energy: (a) geothermal heat pipe/thermosiphon - vertical, (b) geothermal heat collectors - horizontal and (c) ground-water heat pump system, as Fig. 3.17 shows.



(a) (b) (c)

Figure 3.17 Shall geothermal energy utilization - Heat pump systems: (a) heat pipe/thermosiphon, vertically installed; (b) heat collectors, horizontally installed; (c) groundwater wells heat pump systems. (Images: © BPW Bundesverband Wärmepumpe e.V.[60,61])

However, based on current technology this heat pump is still driven by electricity produced with fossil fuels from power plants, which therefore weakens the renewable level of home energy supply with geothermal energy dramatically. The scales of heat pump with various electricity consumption intensity (kWh/m^2) are determined depending on the

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[60] www.waermepumpe.de

[61] http://www.erdwaerme-thueringen.de/?page_id=122

total building energy system design and heat load of residential building/house. From the ecological and economic perspective, the current challenge is how to achieve a type of heat pump driven by renewable energy. For example, the electricity for running the geothermal heat pump is from districted wind and hydropower, as well as solar panel on the roof.

In general, from architectural and engineering perspective the heating and cooling loads of residential buildings are comparatively less influenced by architectural form and building orientation (e.g. floor plate geometry, number of storeys, presence of balconies, arrangement of functional zoning etc.) than thermal characteristics of building envelope (e.g. U-value of walls and windows, g-value measuring the solar energy transmittance of glass in Europe or solar heat gain coefficient in the United States). This is why the main differences between green building and conventional building lie in insulation, ventilation, availability of renewable energy and access to using the wasted heat. For instance, R-value of insulation materials in green building is always higher than in conventional building, and instead of plain glass, the windows of green building are reflective glass to reduce the heat transfer into the interior space of building, and so on.

Actually, residential buildings with more energy-efficient elements have been developed in the recent decades, which have many advantages. For example, occupants in those buildings feel well with comfortable and stable indoor temperature and air quality, and a tightly sealed air/vapour retarder without annoying noises reduces the likelihood of moisture and air seeping through the walls. However, residential buildings with high technologies also have potential disadvantages, such as more costs and longer construction period than a conventional home, as they may need more training for occupants if they have no experience with these new systems, and meanwhile the willing of builders and contractors to deviate from what's they are used to doing may be a hinder to invest energy-efficient technologies.

The aim of residential building design is to minimize the energy demand during the whole building lifecycle and to maximize the utilization of renewable energy, i.e. from the phase of construction, to of operation and maintenance, and to the demolition and recycling phase. From the perspective of architecture and civil engineering, they make efforts at the beginning of building lifecycle to design high-performance buildings as far as possible, which offer unique features to reduce dependence on fossil fuel and also provide exceptional living comfort. Although many of these features have an upfront cost, they reduce the operating costs throughout its lifespan (Lozanova 2015), after all the energy cost in operation phrase represents the highest share of total energy consumption of building lifespan.

3.3 Influencing factor: Attributes of stakeholder related to residential energy efficiency

3.3.1 Stakeholders

Stakeholders play crucial roles in setting priorities for optimizing energy efficiency in residential buildings with any objective and subjective intervention. The priorities consist of (1) technical feasibility of energy-saving measures; (2) economic profitability, which takes into account the visible profit (e.g., reduction of household energy bill), and invisible profit (e.g., the saved energy cost could be invested in something else that might be more profitable; (3) and potential contribution to environmental and climate protection. Stakeholders involve themselves into the following processes that affect the building energy efficiency significantly:

- Developing energy-saving strategies and regulations.

- Implementing energy-saving measures.

- Evaluating energy-saving achievements.

The main stakeholders of energy efficiency investment in residential buildings refer to:

- Architects, civil and energy engineers. A rational and sustainable plan and design by architects and engineers can improve the energy efficiency in the context of technical influences from the beginning.

- Markets participants such as building operators, energy providers and managers, and utility companies. Following a market mechanism "*Need must be supplied!*" (Katzenbach et al. 2015), the demand response is a noticeable instrument for owners and managers to perceive the necessity and urgency of improving residential energy efficiency from the operational and managing aspects, thereby to implement energy-saving measures for achieving a significant promotion in energy and real estate markets, not only to reduce the operational and maintaining cost.

- Occupants, refer to households who consume energy in their private living spaces for sustaining a normal and comfortable life. As the end-users or direct beneficiaries of energy efficiency investments, the attitudes of occupants towards energy efficiency and their behaviour by energy-consuming at home determine whether energy-saving measures developed by other stakeholders could be implemented effectively, which influence the living conditions of households themselves in turn. From the economical viewpoint, more household expenditure for energy consumption leads to less capital for other investments that could either make living condition better than before or bring extra profit for family. From another point of view, the energy demand strongly influenced by user behaviour actually reflects the users' sensitivity to energy prices and other related energy policies, which are determined by other stakeholders, such as market participants and policy-makers in charge of residential energy supply and management.

- Decision-makers (i.e. municipalities, financing organizations), in the context of house policy and residential energy policy. They are in charge of motivating and supporting effective promotion programs or incentives that introduce users to merge into an energy-saving and sustainable society with a proper and positive way (Katzenbach et al. 2016).

Better energy efficiency saves not only the monthly energy bills for heating, cooling and other electrical household appliances in each household, but also saves the running and maintaining costs for building and energy providers if there is a combination of behaviour change and technical optimization, as well as financial subsidies from the public bodies (Kakalejčíková 2017).

3.3.2 Social backgrounds of stakeholders

"*People are motivated by beliefs and status aspirations*." (Biggart and Lutzenhiser 2006, p.1075).

Energy efficiency has increased over the last decades, however, the net energy consumption rises still. The continuously higher penetration of energy-consuming household appliances and some traditional unsustainable life styles counterbalance initial efficiency gains through technical efforts. The underlying causes of this unexpected offset could be attributable to:

- The complex socio-economic conditions, for example, the size and type of residential units, ownership status (lease or owner-occupation), family structure (e.g., family with multi-generation, single-family etc.), household disposable income for residential energy expenditure, as well as family members' profiles such as gender, age, employment status.

- The psychological variables and cultural attributes of occupants. It refers to the attitudes towards energy conservation, the personal norms and social principle, as well as some entrenched traditional behavioural patterns. These variables are supposed to be influenced by different identities, so-called intend-oriented behaviour, and other contextual or environmental elements (namely impact-oriented behaviour) (Poortinga et al. 2004, p.75), similar standpoint appeared also in Stern's research work (Stern 2000).

Since a few decades, a growing work of research has made to identify the key socio-demographic predictors of residential energy usage, so that many relevant theories, approaches and models were developed, which have different substantive emphasis, for example,

- Value-Belief-Norm (VBN) Theory (Stern et al. 1999), Theory of Planned Behaviour (TPB) (Ajzen 1985 and 1991), Theory on Diffusion of Innovations (Rogers 1983), which aim to explain how occupants in a certain social system accept and spread new energy-saving measures.

- Attitude-Behaviour-external Conditions (ABC) Model (Guagnano et al. 1995), Behaviour Model of Residential Energy Use (Van Raaij and Verhallen 1983), Social-Psychological Model (Costanzo et al. 1986), which aim to interpret the influence processes and behavioural change related to energy conservation.

- Time-Geographic-Diary Approach together with interviews to analyse and understand household energy consuming activities in daily life (Ellegård and Palm 2011), which is very important for developing policy that is capable of promoting sustainable life for residents.

- the concept of Quality of Life (QOL) derived from Maslow's Hierarchy of Needs Theory (MHNT)[62], which could be adopted to evaluate household energy usage.

- Gram-Hanssen used practice-theory in her research as an approach to explain both unconscious habits and technological structures in context of households' energy consumption, particularly with her research case to show the significant variation in energy consumption owing to different household energy-consuming patterns and heating system in the residential building in Denmark (Gram-Hanssen 2010 and 2013).

Socio-economic conditions seem to be "real factors" implying the opportunities/capabilities or constraints that encourage or restrict individual energy conservation behaviour, while psychological variables are deemed to be "perceived factors" (Abrahamse and Steg 2011, p.31), which could influence the extent of household energy saving when those "real factors" are concerned. Each impact of both factors shapes household energy consumption patterns and influences energy conservation at different extent. In many cases the age structure is a most likely negligible reason for energy conservation, however, it has been proved that the age structure affects energy consumption considerably, particular heating energy demand. For example, young families are easier to control their thermal

[62] Maslow's hierarchy of needs is a theory in psychology proposed by Abraham Maslow. It is used to study how humans partake in behavioural motivation intrinsically.

energy consumption than old ones, because old people spend normally more time at home and lack enough knowledge of energy conservation, and it seems harder for them to change their habits and accept new energy efficient measures.

Another “real factor” is the employment. Occupants with employment have normally relative lower occupancy rate than unemployment or retired families. Meanwhile, employment status determines household income that influences the affordability of energy efficiency measures and products, as well as the choice of residential energy carriers too. For example, households with higher income prefer to use gas for space heating, whereas the reverse turns to oil or solid fuels (Carraro et al. 2011, p.13). It is noteworthy that on the one hand high-income families are likely to spend more energy than middle- and low-income ones because rises in income broaden the options they can engage in and afford, and thus increase the total amount of material goods and energy needed for better quality of home life (Schipper et al. 1989, p.273). However, on the other hand, EIA through a survey of heating energy costs in residential buildings found out that a relatively lower proportion of heating costs in high-income households than that in low-income ones. For example, households with at least $120,000 annual income spend nearly 39% of their household income for space heating, while 44% of household income was spent by families with less than $20,000/a. It could be explained that high-income families can afford good quality houses or dwellings, which reduce energy loss from the technical side to a degree, in addition, these families have more opportunities and better abilities to receive advanced technology and information about residential energy efficiency, therefore to improve their energy-saving awareness.

Education is considered as one of socio-economic determinants of technology adoption (Carraro et al. 2011, p.15). Occupants with higher education background seem more open-minded to change their traditional inefficient behaviour and attempt to new energy-saving products and services.

The type of residential units (e.g., multifamily residential units, detached house, detached/semi-detached house), the size and condition (e.g., efficiency of energy equipment, access to solar or geothermal energy, insulation levels) are the physical characteristics that could be regarded as one of socio-demographic variables, as it depends in a large part on other variables, such as size of family and household income. Holloway et al. found out in their study that households living in single-family houses consumed 74% more electricity than those in multi-unit dwellings and correspondently produced more greenhouse gas emissions (Holloway and Bunker 2005, pp.6-7).

Homeownership status plays a complex role in residential energy efficiency. Tenants are not willing or capable to invest energy efficient measures in rented living units, but it should distinguish whether energy expense is included in rent (e.g., Kaltmiete or Warmmiete[63] in German rent system), or if tenants receive any subsidize (e.g., people who live in rented social housing or low-income housing). By contrast, homeowners are more inclined to invest their houses or dwellings with energy efficiency measures for a plus on housing valuation, to receive a higher return from investment in the future. Homeowners appear also better awareness on energy conservation than tenants obviously. An opinion of Barr et al. in their research work considered that ownership might engender a sense of belonging and personal control that motivates the individual to think more consciously about how to save energy (Barr et al. 2005, pp.1442-1443).

Some statistics show that size of family determines energy consumption as total but large families normally have significant strength to minimize energy consumption per capita than small ones.

A bulk of research results have drawn a similar viewpoint that firstly socio-demographic conditions of household give more leverage on household energy efficiency than psychological variables. It means on the one hand, people are prone to change behaviour only when a number of practical conditions are met, particularly if the individual economic circumstance is permitted to pay an additional cost for improving energy efficiency. For example, some one-off home efficiency measures (e.g., retrofit or modernization, additional outlay on energy-efficient technology) are more acceptable in high-income families than low-income ones. Low-income households may prefer some cheap measures to help them benefit from the change of behaviour and technological optimization (Frederiks et al. 2015, p.599). On the other hand, monetary instrument seems to contain more "incentive" capability than mere instructing ways (e.g., oral or verbal education and dissemination of energy-saving knowledge and information) to encourage people to adapt their energy-related behaviours towards the efficient side. Poortinga found in their research that merely 2% of the variation in home energy consumption was explained by only attitudinal variables, however with socio-demographic variables together those psychological variables explained 15% of household energy using variation (Poortinga et al. 2004, p.85).

Socio-economic and psychological variables affect residential energy efficiency at different degree and shape energy-related or environmental-concerned attitudes and behaviours to a certain extent. Given sufficient technical supports and services, social impact factors determine the dynamics of energy problems in context of residential sector, because these factors influence the occupants‘ acceptance to technical optimization, shape the risks that occupants could confront (Sovaccol et al. 2015, p.95), and imply an important juncture for individuals, communities, institutional section and decision-makers to develop targeted household energy-saving measures and policies effectively. Therefore, it is imperative to identify attributes of both impact aspects before performing energy efficiency

[63] Kaltmiete: rent excluding service charges; Warmmiete: rent including operation costs and heating costs.

measures for households, to ensure that strategies or policies are more customized and tailored, as well performed effectively. In many instances, decision-makers focus too much on economic and regulatory factors, however, it has been always suggested and emphasized by researches or other social actors that politicians would be well advised to consider, as well, what is known about social psychological motivations such as social norms, psychological transaction, etc. (Cialdini and OPOWER 2010).

3.3.3 Diversity of occupant attitudes and behaviours

U.S. Department of Energy (DOE) states that a series of activities need to be undertaken to reduce non-technological barriers to increased energy productivity (U.S. DOE 2011, p.69). In term of home energy efficiency, the most important non-technological barrier should refer to all the unexpected results caused or determined by energy-related attitude and behaviour of occupants. Sonderegger found out in his research that physical features could explain about 54% of the difference in energy consumption of households, while the remaining 46% could attribute to the variance of behaviour patterns of consumers (Sonderegger 1978).

Due to the different socio-demographic background and psychological attributes, household energy-related attitudes, behaviours and therefore resulted energy efficiency present significant disparity and diversity. The investigated aspects refer to on the one hand the long-standing and traditional lifestyle and domestic energy use patterns of the individual, one the other hand the lack of knowledge about household energy conservation and access to necessary information. The energy-wasteful lifestyle and behaviours appear normally in a form of unconscious and habitual activities, and significantly influenced by social and environmental factors discussed above. However, the later depends on the availability of energy efficient information and technology, which could be improved through a co-operated performance by all the stakeholders, in particular, public utilities and decision-makers. Tab.3.6 states primary characteristics of energy-related attitudes and behaviours of occupants during the daily life.

Table 3.6 Social factors affected energy-related behaviour and attitudes of households

Concerns	**Views**	**Forms**
Energy concerns:	- Individual contribution to alleviate energy crisis - Impact of individual behaviour on social justice (e.g., private energy consumption on reasonable resource allocation in context of society)	Attitudinal Attitudinal

Ecological consideration:	- Pro-environmental [1] - Very less contribution of individual behaviour change to environmental protection	Attitudinal Attitudinal
Price concern:	- Knowledge of energy prices - Response to fluctuation of energy price (e.g. possibly energy consuming in off-peak period) - Purchase decision for energy-efficient household appliances	Informational Behavioural Behavioural
Perceived behavioural control:	- Self-intention driven behavioural change (i.e. "self-enhancement"[2] or "Pro-self"[3]) - Circumstance-impact driven behavioural change (i.e. "Pro-social"[3])	Instinctive motivated

([1]Karp 1996, [2]Schwartz 1992, [3]Cameron et al. 1998, p.678)

These social factors affect occupant attitudes and behaviour during energy consuming. For example, some households prefer to place the priority on living comfort instead of frugal and environmental lifestyle, if their economic conditions permit. It affects not only during their interaction with heating system, warm water heater and lighting at home, but also in the purchase behaviours, liking preferring to high one-off investment for low-cost usage in the future or conservative consuming capability but long-term higher energy expense. In terms of energy-related occupant behaviour, this research thesis focuses only on the occupants' activities during the energy-consuming phase, i.e. excluding the purchase phase for energy-efficient services and products.

Analysis of occupants behaviours by energy-consuming at home is a considerably complex process, which refers to the individual requirements on living comfort, such as indoor temperature and humidity, size of living space, also to the technological characteristics, energy prices and household income. These aspects could affect the choices of household energy use patterns. In spite of significant improvement of efficiency of residential building insulation and energy equipment, the quantity of energy consumption for residential buildings, in particular for space heating/cooling in total or per capita is rising steadily. It might be attributed to two reasons:

- Firstly, an increase of average living space. As the average size of house or dwelling rises, more energy is demanded for space heating and cooling. With the concomitant minimization of household size, the energy demand per capita has become obviously larger than they actually need, in other words, larger houses are being shared by small families.

- Secondly, rising comfort threshold, i.e. higher indoor temperature in winter and lower in summer than before. The emergence of this phenomenon is ascribed to frequently extreme weather in recent years, like chilly weather in winter or severely hot summer weather.

In most EU countries the energy for space heating takes the main part of household energy consumption, for example in Germany energy consumption for private room heating accounted for about 71% of the total residential energy consumption in 2015 (BDEW[64], DESTATIS[65], the RWI Essen[66], AGEB[67] 2016), the corresponding energy cost for it was about 50% of the sum of residential energy expenditure (AGEB and DESTATIS 2017).

Except for heating with gas or oil, the household electricity consumption is also the main energy consumption in residential buildings, which varies in a large-scale and depends on different factors. For example, average electricity consumption in residential sector worldwide ranges widely from zero in poor regions (mostly in rural area of poor countries) to more than 16,660 kilowatt hours per year in urban Norwegian dwellings, where electricity is a very common and traditional energy with the highest scope of use, from space heating to cooking and all of the other household appliances (RRojas Databank 2008, p.171). In addition, energy consumption for air conditioners rises continuously in urban areas of both developed and developing countries. In many cities of Southern China, people spend more than three-quarters of summer electricity demand for cooling with air conditioners, even in wet cold winter air conditioners are used as an auxiliary heater except normal electrical room heaters, where there is not a central heating system. Household electricity consumption depends on the number and size of appliances, the household lifestyles, and is affected by the energy saving consciousness, the average and peak electricity prices and climate conditions.

The expected or predicted energy use in residential buildings is based on the design information and simulation models, however, the actual use is affected by various factors. The key amongst these is the intervention of occupants. Several studies (Abrahamse et al. 2005, Janda 2009, Ramos et al. 2015, Yan et al. 2015, Hong et al. 2017) showed that occupant behaviours affect the residential energy consumption largely. Guerra Santin et al. studied the impacts of occupant behaviour on heating in Dutch residential stock and found out that a significant difference in heating energy consumption attributed to the interaction between occupants and the heating system. Martinaitis et al. concluded in their

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64 BDEW: The Federal Association of the Energy and Water Industries of Germany (Bundesverband der Energie- und Wasserwirtschaft e.V.)

65 DESTATIS: The Federal Statistical Office of Germany (Deutsches Statisches Bundesamt)

66 RWI Essen is a leading economic research institute in Essen, Germany, full German name RWI – Leibniz-Institut für Wirtschaftsforschung.

67 AGEB: AG Energiebilianzen e.V.

research that the main contributors of the gap between the predicted and actual energy performance of residential buildings are occupant preference and energy-related behaviour (Martinaitis et al. 2015). More specifically, occupants interactions with building energy system include occupancy rate, the energy-related preference of occupants, and the concrete behaviour.

In brief, socio-economic backgrounds and psychological attributes, and therefore resulted attitude and behaviour affect almost the whole process to improve residential energy efficiency, i.e. the obstacles at the beginning to persuade occupants of the long-term efficacy of technological measures even if with temporary inconvenience and necessary costs, the efforts to launch strategies smoothly during the performing phase based on active cooperation between suppliers and users, until benefit from technological optimization with correct attitude and efficient behaviour by occupants at the end. An exhaustive research has to be placed within the context including social, personal and environmental attributes, which involve multidisciplinary categories. Fig. 3.18 illuminates the relationship among the impact variables and the reflected attitudes and behaviours (Frederiks et al. 2015, van Raaij and Verhallen 1983).

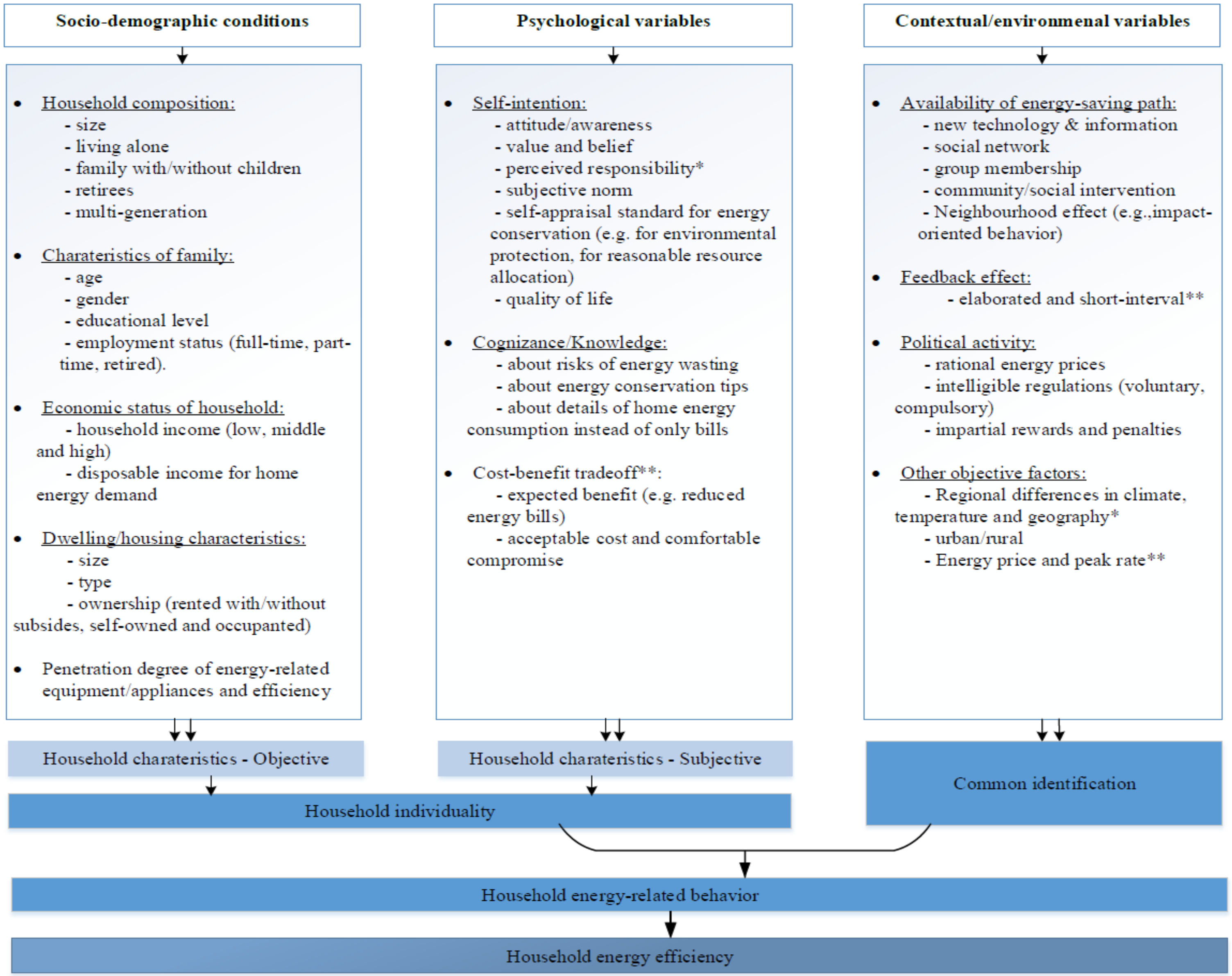

Figure 3.18 Conceptualization of socio-demographic and psychological variables

3.4 Influencing factor: Availability of energy-saving information and services

Informational strategies refer to normally one-way transmission of useful information, knowledges and norms from energy-supplier or government to individual energy user or community. Many studies have proved that an effective information-exchange among households, as well as feedback between households and providers contribute to behavioural change towards energy conservation to a certain high extent. The type of interaction includes a structured evaluation of the effectiveness of interventions, which is important for researchers and decision-makers.

Lack of information is considered as one obstacle of energy conservation (Gillingham et al. 2009). The importance and meaning to identify the correlation of social attributes of energy consumers and their energy-consuming behaviours aim to acknowledge which factors do drive household energy consumption and conservation, therefore to develop more tailored interventions and provide effective information towards different cases. Energy-saving measures are hard to perform well without a robust synergy of information delivery and effective services, which has been underlined by Abrahammse the in his study. He indicated that it was a challenge to structural reform, so that more interdisciplinary studies should engage in for future research in this field (Abrahammse et al. 2005).

3.5 Influencing factor: Political intervention and technical specification

3.5.1 Housing policy (Germany, China, USA)

As discussed above, residential energy efficiency is affected at a certain degree by housing ownership status (i.e. owner or tenant). The predominant view of ownership depends on household economic competence and other long-term intentions of individuals, and few would consider impact of national or regional housing policy. However, over the last decades housing policy has been significantly reformed due to the changing demographic and economic situation, as well as a constant urbanization, not only in most developing countries or those with economic transition, but also in developed countries where are experiencing an increasing trend for owner occupation than previously mainstreamed tenure forms. For example, Germany, where the trend of home purchase has a clear rise since recent years with underlying reasons, such as cheap loans of housing procurement and favourable mortgage options, which make real estate more affordable and provide more attractive ways than other common investments.

Housing policy has long been regarded as a derivative policy of other political formulation and it is implicated in multidisciplinary concerns, for instance, energy policy reform, national welfare policies and tax system, as well as urban planning system etc. Hence, housing policy has crucial importance for national legal systems because it makes a reasonable contribution to one of the most basic human needs - Housing for living (Cornelius and Rzeznik 2014, p.39). Meanwhile, housing policies drive or challenge other relevant industries to a certain extent, such as building material industry, real estate industry and housing financing market, household goods including domestic electrical appliances sectors, as well as the urban labour market. Each reform of housing policy could cause an obvious change of ownership status and therefore affect energy-related occupant behaviours and their energy consumption. Fig. 3.19 shows a simplified relationship of housing policy and final residential energy efficiency.

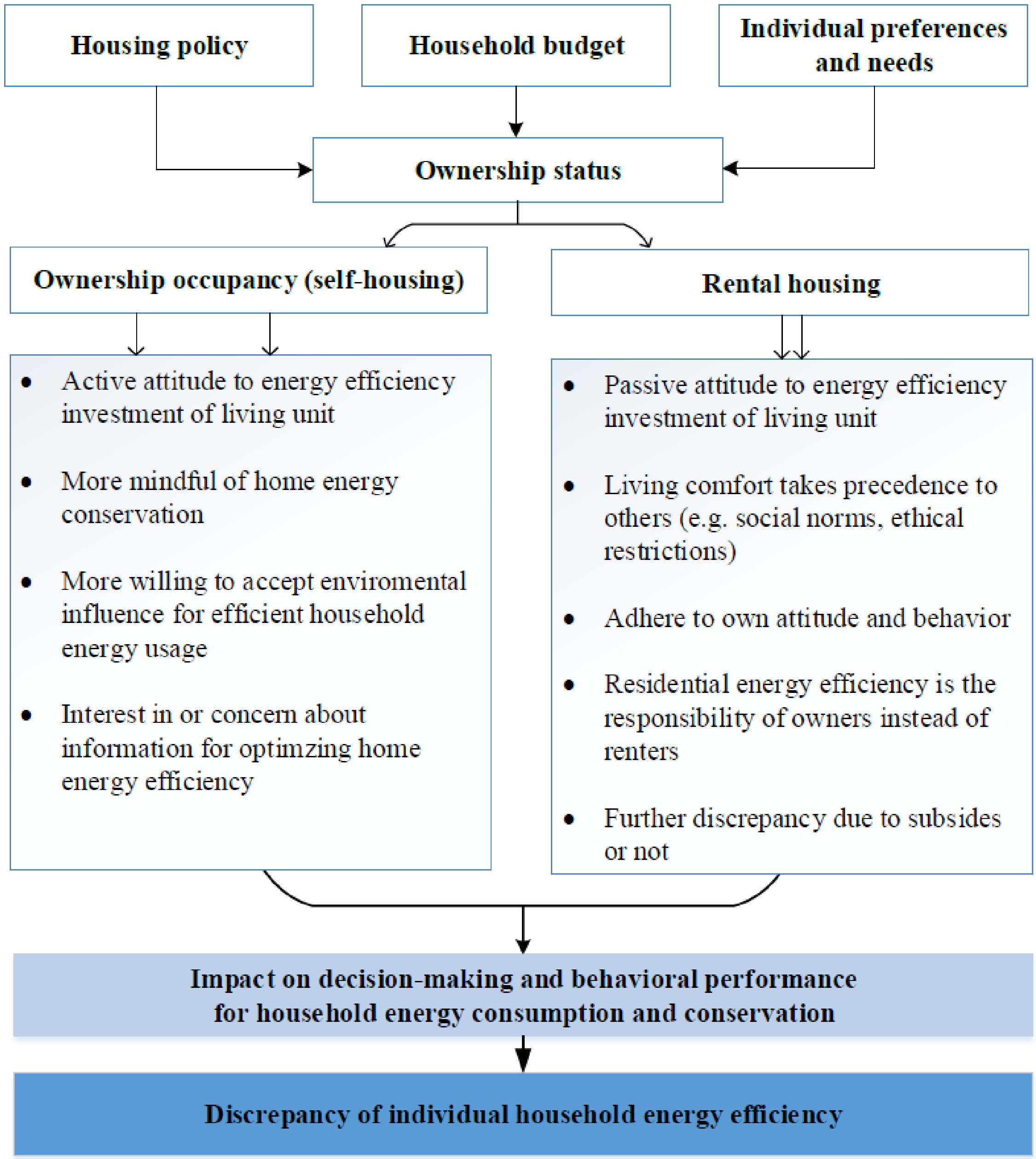

Figure 3.19 Relationship of housing policy and residential energy efficiency

Enacting housing policy depends on the development dimension and dynamics of all parts of society. In different periods of social development, housing policy favours different tenure types (e.g. home ownership or rental housing). Since house policy reflects, in a way, the political ideology of the government in power, there are considerable variances in objectives of housing policy among countries (Zenou 2012, p.398).

Germany

Since recent years the real estate market in Germany has appeared to more attractive and safer capital market than ever, but in comparison to other EU member states, the home-ownership rates is still the lowest (e.g. 47.5% of households have their own real estates in 2014). This phenomenon might be explained by the German rental system, which is a key factor contributing to the stability and affordability of the housing market. The relevant political system is highly sensitive to the rights of tenants and the potential threats to them, i.e. the German rental system do the best to protect tenants from fluctuated rents and any unreasonable termination of leases or eviction by property owners, as long as tenants pay the rent on time and behave well. The German Housing Policy is based on different policy instruments. For example, the Tenancy Law[68] explicitly defines the rights, responsibilities, options and restrictions applicable to tenants and property owners. The Housing Allowance[69] is intended to provide adequate and family-friendly housing for economic security, as well not only is paid as a subsidy for rent, but also is allowed to be applied by people who cannot afford the self-occupied housing within their household budgets (§ 1 WoGG[70] 2008, p.3). As a result of the changes in social law - Hartz IV, The Fourth Law for Modern Services in the Labour Market, which came into effect on 1 January 2005, the households with the right to the housing allowance and thus recorded housing payments have been significantly reduced. Since then the reasonable accommodation costs have been taken into account in the respective social benefits.

The core instrument of German housing policy was the relevant regulation of social housing, which is a part of the German Social Housing Act[71]. It defines expressly that the target group of social housing promotions is households that cannot adequately supply themselves with living space at the market prices and are proved as a support-dependant social group. German government sponsors social housing program with economic assistance aiming towards alleviate housing costs and expenses for poor citizens with low to moderate incomes.

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68 The German Tenancy Law: Mietrecht in German, §§ 535 - 580 of BGB (Bürgerliches Gesetzbuch).

69 The German Housing Allowance: Wohngeld in German, is a social benefit in Germany under the Housing Benefit Act (WoGG in German) for citizens who receive a subsidy for rent (rent subsidy) or home ownership (load subsidy) due to their low income.

70 WoGG: The German Housing Benefits Law, Wohngeldgesetz in German. WoGG regulates the support of the state by housing subsidies in Germany.

71 The German Social Housing Act: Gesetz über die soziale Wohnraumförderung (Wohnraumförderungsgesetz - WoFG) in German.

The concern of energy efficiency in social housing is of particular significance in Germany, as the housing subsidies provided by government contain a fee or part of fee for household energy expenditure. In that case, it would lead inevitably to a weak energy-saving awareness and hence to an inefficient residential energy performance. Therefore, a system of combined housing and social policies shall be established, which has to clearly identify responsibilities for housing management and occupants, with the help of informational initiatives and financial mechanisms.

China

Housing system reform in China[72] was initiated in the late 1980s. The housing system reform is an important part of China's economic system reform and its goal is to ensure the housing security for urban residents with various income levels.

Before the 1990s, a welfare housing system was the main housing system in China, which principally provided urban residents (referring mainly to the urban employees of state-owned enterprises) the living space in form of rent. With the expansion of urbanization, this system imposed heavy burdens on those enterprises and also significantly lowered the efficiency and fairness of housing provision (Li 2016, p.19). Therefore, the necessity of housing system reform emerged to meet this historic destiny, which was to achieve a gradual transition from welfare housing system to commodity housing system (i.e. a monetized housing allocation system). Commodity housing policy has been implemented until the present and underwent many reforms, as illustrated in Table 3.7.

Table 3.7 Housing policy reform of China

Housing system	Target population & characteristics	Enactment	Effectiveness
Low-rent housing	- People, who cannot afford to by housing or for the migrant workers (moving from rural to city for better work and life) - Diverse housing, including new housing,	It was proposed in 1998, however it seemed to be too unattractive for property developers due to lack of profitability to be left out, and until 2006 this policy was requested to	From the current practice of view, the existing number of low-rent housing couldn't cover all the eligible population, because its application criteria is so strict that many

[72] Research on housing policy in China in this doctoral thesis relates to only policy in Mainland China, excluding Taiwan, Hong Kong and Macao.

	vacant real estate, refurbished housing, old public housing and so on - Only rent not sell	be strengthened again because of the price soaring of commodity housing and the questioned economically affordable housing.	applicators are excluded from the rental standard, but they still cannot afford commodity housing.
Economically affordable housing (EAH)	- Urban residents who belong to low-income households and cannot afford housing at the market price. - EAH is defined as "the commodity housing with the nature of social security", which is funded by government. EAH aims to support the economy and applicability of urban housing, i.e. the housing prices relative to the same period the market price is moderate and suitable for middle and low-income families, so-called economy. The applicability refers to the housing construction standards must be guaranteed. - New housing - Rent or sell	It was proposed in 1994.	Since this housing provision system did not receive a great success as expected, economically affordable housing disappeared from official documents after 2008 (Victor Jing Li 2016, p.23).
Commodity housing	All people who can afford the housing at market prices.	It has been initiated since 1980s.	The main housing provision form in China

In order to initiate "Home Ownership Scheme" on the one hand, also to support the commodity housing policy on the other hand, the Housing Provident Fund (HPF) policy plays a significant role to help urban residents (mainly middle and low-income workers and employees) meet their housing needs, e.g., buy or rent housing/dwelling at market prices. Housing provident fund rate is determined based on local economic level, the revenues and profits of enterprises, working years of employees and others.

Besides, in China, the Ministry of Housing and Urban-Rural Development (MOHURD)[73] takes responsibility for the basic housing provision and the corresponding housing right. According to the Basic Housing Provision Act[74], local authorities are in duty to make annual plans for building and allocating social housing, which have to coordinate with the overall planning on urban development.

Housing policy in China affects the energy efficiency in a particular context, which involves energy-pricing mechanism, the market incentive for building developers and consumers, and public transparency and effective information transfer, so-called Lemon Market[75] effect. In the current situation, the energy pricing mechanism und the supply system in China, in particular heating supply system, remain still very strong characteristics of plan economy. Consumers have few opportunities to access the control of energy supply systems and even to choose and manage the energy services in some cases. Alternatively, the lack of enough energy-saving measures, residential buildings is still a barrier for improvement of building energy efficiency. Throughout the real estate market in China, it is still short of economic incentives for building developers to build energy-efficient but high-cost residential units. The investment of high-efficient residential buildings from governments lacks enough transparency too. In addition, transfer of building energy-saving information towards consumer is not enough and comprehensive, thus failing to attract more consumers to pursue high energy performance residential units and behave high energy-efficiently.

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[73] The Ministry of Housing and Urban-Rural Development (MOHURD) 中华人民共和国住房和城乡建设部, http://www.mohurd.gov.cn/) is a ministry of the government of the People's Republic of China, which provides housing and regulates the state construction activities in the country.

[74] The Basic Housing Provision Act:《基本住房保障法》in Chinese. This Act involves housing demolition and relocation of inhabitants, housing quality, residential facilities, housing security, and housing provident fund and so on.

[75] Lemon Market: American economist published a paper "The Market for Lemons: Quality Uncertainty and the Market Mechanism", which examines how the quality of goods traded in a market can degrade in the presence of information asymmetry between buyers and sellers.

USA

The U.S. Federal Housing Administration (FHA) instituted the first national housing programs since its inception in 1934, e.g., FHA's mortgage insurance programs help low- and middle-income families meet their own property by lowering some of the costs of their mortgage loans, meanwhile protects lenders against losses as the result of homeowners defaulting on mortgage loans for properties. To the mid-1970s, the U.S. federal government devised, funded, and implemented virtually all housing programs (Buckley and Schwartz 2011, p.9). Same like many other countries, the U.S. government has implemented various housing policy instruments to pursue an optimized housing provision system for different target groups. It allows being divided into two policies: the U.S. low-income rental housing policy and homeownership policy. Various instruments have been implemented through both policies.

The Low-Income Housing Tax Credit (LIHTC) is one of the single largest subsidies for low-income rental housing in the U.S., which is not a federal housing program but an item in the Internal Revenue Code (IRC)[76] (Buckley and Schwartz 2011, p.10). It provides financial incentives to invest in low-income rental housing. This program accommodates more households than public housing. (Schwartz 2006, p.83).

The Homeownership Rate is still the main form in the U.S. housing market. It peaked at over 69 per cent in 2004 (Olsen and Zabel 2014, p.64) and has shifted downward since then until 63.7 per cent in 2016, according to the statistics on residential vacancies and homeownership for fourth quarter 2016 by the U.S. Census Bureau. This phenomenon could be explained a long-term housing policy during the post-war in the U.S., e.g., many changes happened in the mortgage finance system and the federal income tax code reduced investment in rental housing but paid more attention to or favoured homeownership (Buckley and Schwartz 2011, p.3). Besides the direct expenditure, the Internal Revenue Service (IRS)[77] administrates also the tax expenditures to owner-occupants for housing consumption specified in the personal income tax code.

In addition, the U.S. government has developed many programs to meet the growing housing needs of the population, for example, the Hope VI[78] program contributing to redeveloping or transforming public housing to more suitable housing forms, and housing

[76] The Internal Revenue Code (IRC), formally the Internal Revenue Code of 1986, is the domestic portion of federal statutory tax law in the United States and the main body of federal statutory tax law of the United States.

[77] The Internal Revenue Service (IRS) is the revenue service of the United States federal government. IRS is responsible for collecting taxes and administering the Internal Revenue Code.

[78] Hope VI is a plan by the United States Department of Housing and Urban Development. It is proposed to revitalize the worst public housing projects in the United States into mixed-income developments.

vouchers program for low-income households to rent housing with the price more than 30 per cent of their household income.

3.5.2 Building energy conservation codes (Germany, EU, China, USA)

Building energy conservation codes (also building energy codes) can be understood as a set of rules that specify standards for building constructions in terms of energy efficiency and provide the minimum efficiency requirements for new and retrofitted buildings. Building energy codes are responsible on the one hand for ensuring new building construction according to high energy conservation standards, on the other hand to explore energy-saving potential when retrofitting of existing buildings, and both aim for reductions in energy use and emissions over the life of buildings.

Aiming to optimize building performance and guarantee the sustainability of social and environmental entities, most countries have set up a series of standards and regulations for rating building energy efficiency, which is similar to energy labels for household electrical appliances. These standards and regulations work as an indication of building energy performance.

A comprehensive building energy rating system covers energy use for space heating and cooling, domestic hot water supply, ventilation and lighting and household appliances, which are determined by efficiency level of building construction and energy equipment, and is calculated based on occupancy information and adequate analysis of occupants behaviours. Building energy codes represent significant saving opportunities for developers and occupants. Different rules and regulations, building standards and codes shall respond to the needs and context of each country and take into account local climate and economic conditions, as well they shall be framed and enacted for promoting energy efficiency of building system. The following part introduced the building energy conservation codes and standards in different countries, i.e. Germany, EU, China and the U.S.

Germany

Documents evaluating a building energetically in Germany are named Energy Performance Certificates (EPCs) (German: Energieausweis or Energiepass), which records the main information of building energy efficiency, describes minimum requirements regarding energy use of new and renovated buildings and indicates whether renovation would make sense in each case. EPCs are regulated in the German Energy Saving Ordinance (EnEV). Enforcement of EPCs aims to assess energy efficiency in building construction, which is classified into nine levels from A+ to H based on final energy demand of building according to the requirements of EnEV for residential buildings, as Table 3.8 showed. Since 1st October 2009, a statement about utilization of renewable energy and ventilation concept was supplemented.

Table 3.8 Energy efficiency classification in EPCs for residential buildings[79] (Source: Verbraucherzentrale NRW[80])

Energy Efficiency Class	Energy demand or Energy consumption	Approx. annual energy costs per m² living area
A+	< 30 kWh/(m²a)	< 2 Euro
A	30 ~ 50 kWh/(m²a)	3 Euro
B	50 ~ 75 kWh/(m²a)	5 Euro
C	75 ~ 100 kWh/(m²a)	7 Euro
D	100 ~ 130 kWh/(m²a)	9 Euro
E	130 ~ 160 kWh/(m²a)	12 Euro
F	160 ~ 200 kWh/(m²a)	15 Euro
G	200 ~ 250 kWh/(m²a)	18 Euro
H	> 250 kWh/(m²a)	≥ 20 Euro

For new residential buildings/houses, EnEV 2014 has set standards for envelopes, windows, roofs and other building components clearly, i.e. the permitted maximum U-value of building components[81]. New built residential construction must abide by the following criteria:

- Annual primary energy requirement Q_P is measured for installed energy system in kilowatt-hours per square meters and per year, [kWh/(m^2•a)].

- Specific transmission heat loss H'_T is measured for building envelope in kilowatt-hours per square meters and per year, [W/(m^2•K)], as equation 3-4.

$$H'_T = H_T/A \qquad [W/(m^2 \cdot K)] \qquad (3\text{-}4)$$

[79] This classification took effect from May 2014.

[80] Verbraucherzentrale NRW: The Federation of Consumer Organisation of state North Rhein-Westphalia (NRW), Germany, https://www.verbraucherzentrale.nrw/

[81] EnEV 2014, Annex 1, Table 1: „Ausführung des Referenzgebäudes". http://www.enev-online.com/enev_2014_volltext/enev_2014_anlage_01_anforderungen_wohngebaeude.pdf

where,

> H_T: the transmission heat loss, which is calculated under the conditions in Appendix D2, Table D.1 of DIN V 4108-6 revision 1: 2003-06.
>
> A: the heat-transferring perimeter area, which according to DIN V 18599-1: 2011-12 Chapter 8, is defined as the enveloping surface that is the boundary between conditioned spaces and ambient air, soil or unconditioned spaces.

EnEV provides the calculation methods for Q_P and H'_T that are conducted according to DIN V 18599 and DIN V 4108 respectively, which was already described in chapter 2. The maximum Q_P and H'_T are defined in EnEV 2014 (Annex 1, Table 2) depending on the type of residential buildings, owing to different factors to determine the effective building areas A_N. Except the calculation method mentioned in chapter 2, A_N could be simply calculated in following situations:

- for single-family or two-family houses with a heated basement, $A_N = 1.35 \cdot A_{living}$
- for other residential units, $A_N = 1.2 \cdot A_{living}$

In addition, the characteristics of heating system play an important role in determining maximum Q_P. For example, according to EnEV the upper value of Q_P for a detached house is 88.48 kWh/($m^2 \cdot a$), which is equipped with oil- or gas-condensing-boiler combined with solar domestic water heating. While the detached house equipped with air/water-heat pump or brine water/water-heat pump, the Q_P could be reduced to 76.71 kWh/($m^2 \cdot a$) or 66.63 kWh/($m^2 \cdot a$) respectively.

EnEV is a part of the German economic administration law and describes the requirements on building technology for an efficient energy performance during building operation phase. EnEV applies to residential buildings, office buildings and certain commercial buildings, while others are exempted[82]. Besides, the German Renewable Energies Heat Regulation[83] specifies the renewable energies (e.g. solar energy, biomass, geothermal energy) as complementary or alternatives for residential energy supply, which aims to increase the share of renewable energy for heating and cooling purpose. Especially for new buildings, the EEWärmeG requires that a certain amount of electricity for space heating is covered by renewable energy.
At present, private housing and most commercial buildings in Germany must be built abiding by the requirements of EnEV in order to obtain a building license for sales, rent

[82] EnEV, Abschnitt 1, § 1 Zweck und Anwendungsbereich. Revised on 18th November 2013

[83] The German Renewable Energie Heat Regulation: Erneuerbare-Energien-Wärmegesetz (EEWärmeG) in German.

or self-occupy. Therefore, it is required that each person or household who is planning to build a new building or house, renovate or extend the old residential unit, rent or buy one, must be aware of the following three nationwide energy saving schemes:

- Energy Saving Ordinance (EnEV)

- Renewable Energy Heat Act (EEWärmeG)

- Energy Conservation Act (EnEG)

The EPCs templates for residential building are introduced in Appendix 1.

EU

Energy Performance of Building Directive (EPBD)[84] and Energy Efficiency Directive 2012/27/EU (EED)[85] are the EU's main legislation covering reduction of building energy consumption. In November 2016 European Commission (EC) proposed an update to the EPBD and EED aiming to help promote the use of smart technology in buildings, and to streamline the existing rules.

EC launched a new observatory in November 2016, named EU Building Stock Observatory, to keep track of the characteristics and energy performance of Europe's buildings in the way of monitoring. This Observatory consists of a database, a data mapper and fact sheets that contain all relevant information on energy performance of buildings across Europe, in particular residential buildings built before energy performance relations began to enter force in the 1970s. The information is invested under different categories referring to building stock characteristics, building shell performance, technical building systems, energy consumption and Nearly-Zero-Energy buildings, as well as energy market and energy poverty. Based on the gathered information in its database the Observatory also provides details about what makes buildings energy efficiency[86].

In addition, the Energy Performance Assessment of Existing Dwellings (EPA-ED)[87] was a research project developed by EU, which dealt with professional solutions and energy consulting for existing residential building and focused on the implementation of the EU

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[84] The first version of the EPBD, directive 2002/91/EC, was approved on 16 December 2002 and entered force on 4 January 2003.

[85] The first version of the EED, also Energy Efficiency Directive 2012/27/EU, was approved on 25th October 2012 and entered into force on 4th December 2012.

[86] https://ec.europa.eu/energy/eubuildings

[87] http://www.buildup.eu/en/explore/links/epa-ed-energy-performance-assessment-existing-dwellings

building guidelines for them. The EPA-ED method enabled energy consultants to examine and evaluated a residential building or house with a standardized procedure, so that the building owners can therefore obtain the tailored proposals for energy saving in own buildings or houses, pertaining to thermal insulation, window replacement, highly efficient boilers or the installation of solar panels and so on.

China

Urban residential buildings are a critical priority area for energy technology and policy engagement, as urbanization, floor area growth and increased access to electrical household appliances continue to drive total energy consumption (IEA & Tsinghua University 2015, p.25). According to the national "Standard of Climatic Regionalization for Architecture", there are five zones in China divided based on climate characteristics: very cold, cold, hot summer and cold winter, hot summer and warm winter, and moderate (as shown in Figure 3-20), where different building energy efficiency codes and standards are required to adapt to different geographical and climatic environment. Therefore, three Design Standards for Energy Efficiency of Residential Buildings were developed for severe cold and cold zone, hot summer and cold winter zone and hot summer and warm winter zone. In addition, special codes for acceptance of energy efficient building construction and for testing the energy efficiency of residential buildings are developed for ensuring the construction procedures with high quality. Details of codes and standards are illustrated in Appendix 2.

Figure 3.20 Climatic Regionalization for Architecture in China

Design standards for energy efficiency of buildings in China clarify the goals of energy conservation and promoted energy-saving measures, specified for residential buildings (Xu 2014):

- reduction of energy consumption for air conditioners and space heating under the condition of maximum comfortable and healthy indoor environment.

- 65 per cent reduction of energy consumption for heating, ventilation and air conditioning until 2014 compared to the levels of the early 1980s, particularly in severe cold and cold zones.

- Nearly-zero-energy buildings are pursued until 2030.

The main technical measures for achieving those goals are:

- improving the insulation of building envelope and other energy equipment (e.g., pipe), improving airtightness of building construction.

- increasing the efficiency of heating, ventilation and air conditioning equipment and systems.

- renewable energy alternative to conventional fuel energy.

- optimized building energy system operation strategies (e.g., optimization of central heating supply system in most northern regions).

Building energy conservation standards in China are launched depending on the practical requirements and regional characteristics, therefore still accompanied with necessary updates. For example, Beijing has implemented mandatory energy saving design standards for new residential building since 1991, and some residential buildings that were not designed according to these standards could not receive permission to be built. It was proven that the residential energy consumption from 1991 to 2003 was reduced by nearly 50%.

China has begun to design a green building evaluation system since the early 2000s. The first China's Eco-House Technical Evaluation Handbook was developed in 2001 and since then the updated editions with the most recent progress were released. In 2006 the Ministry of Housing and Urban-Rural Development (MOHURD) of China released a national green building standard, which aims to regulate evaluation on green buildings and promote the development of green buildings. The evaluation system has two different standards, i.e. one for residential buildings and another for public (also large commercial) buildings. This system is based on six categories in which the tested buildings have to fulfil different evaluation criteria to attain the three different ratings, so-called "Three Star System" of green buildings. Local governments are entitled to adapt the standards depending on the local environmental and climatic circumstances. Appendix 3 illustrates the different ratings of residential buildings fulfilling varies criteria, which is consisted with 76 options in total, among those there are 27 mandatory options, 40 regular options and nine premium options (Keitsch et al. 2012, pp.213-215).

USA

In the U.S., the International Code Council (ICC) is in charge of administrating the residential building energy code development process. The U.S. Department of Energy (DOE) participates in this process for fostering increased energy efficiency in new and existing homes and low-rise residential buildings by incorporating cost-effective energy efficiency measures[88].

The International Energy Conservation Code (IECC) is a building code created by the ICC in 2000 and works as a model code adopted by many states and municipal governments in the United States for the establishment of minimum design and construction requirements for building energy efficiency (Turner and Doty 2006). DOE is responsible to review the IECC and related standards for saving energy in residential buildings, meanwhile to provide proposed changes with documentation for consideration and submit them for the public hearing process, aiming for promoting those changes to be accepted and implemented. The methodology adopted by DOE for evaluating the energy performance and economic feasibility of residential buildings contains two primary assessments[89]:

- Energy savings calculation, which is conducted through building models using the DOE software EnergyPlus™ [90].

- Cost-effectiveness evaluation (CEA) (Taylor et al. 2015), which accounts for the benefits of home energy-efficient investments, and aims to assess its economic feasibility. Cost-effectiveness analysis considers the economic impacts as far as possible, e.g., increased mortgage costs, tax impacts and residual values of energy efficiency measures.

In addition, the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) committed to developing building standards, which reflect national energy policy and provide guidance for improving the energy performance of new buildings. In particular, ASHRAE developed *Energy Efficient Design of Low-Rise Residential*

[88] https://www.energycodes.gov/development/residential

[89] https://www.energycodes.gov/development/residential/methodology

[90] EnergyPlus™ is DOE's open-source whole-building energy modeling engine, which engineers, architects, and researchers use to model both energy consumption for heating, ventilation, lighting and plug and process loads, and water use in buildings.

Buildings[91] in 2007. This standard applies to new residential dwelling units and their systems, as well as new systems and equipment in existing dwellings units, including,

- building envelope
- heating equipment and systems
- air conditioning equipment and systems
- domestic water-heating equipment and systems
- provisions for overall building design alternatives and trade-offs

These codes and standards are revised or changed every three years.

Similar like green building labels in China and building energy codes in Germany and other EU countries, the green building rating system in the U.S. is the most widely used, also Leadership in Energy and Environmental Design (LEED)[92]. LEED applied to almost all types, from new construction to refurbishment of existing construction and interior fit-outs. It provides a framework and evaluation standards for highly efficient, comfortable indoor climate and cost-saving green buildings. LEED addresses different applicable rules for all possible project types. For example LEED v4 for Homes, which is a residential green building certification that applies to all residential projects (e.g., single-family homes, low-rise multi-family from one to three stories, and mid-rise multi-family from four to six stories, as well from a renovation of existing buildings to new construction). A project checklist performs the evaluation standards of LEED v4 for Homes, including LEED BD+C[93] for Homes and Multifamily Low-rise, as well as LEED BD+C for Multifamily Midrise respectively. Special scorecards addressed in performance checklist evaluate the energy efficiency of tested residential units, and the total possible points are 110. All the energy-related factors are checked to attain a synthetic evaluation of residential energy efficiency, including location and transportation, sustainable site-selection, water efficiency, efficiency of building construction and equipment, energy-efficiency education of the homeowner, tenants and building managers, environmental attributes of materials and resources, indoor environmental quality, possibility of innovation and other regional priority in social equity and public health priorities (USGBC 2013). Appendix 4 and 5 illustrate the LEED v4 evaluation checklists for Homes & Multifamily Low-rise

[91] ANSI/ASHRAE Standard 90.2-2007.

[92] The United States Green Building Council (USGBC) provides third-party certification that a building or community has been designed and built using strategies for improving efficiency of energy use, CO_2 emission reduction, indoor air quality and stewardship of resources.

[93] LEED BD+C: LEED Building Design and Construction

and Multifamily Mid-rise.

Building energy codes are adopted at the state and local jurisdiction levels in the way of legislative action, or regulatory agencies authorized by the authoritative legislative bodies. Once adopted through regulation, the energy codes become law within the particular state or local jurisdiction[94]. Figure 3-21 shows the current national status of residential energy code adoption in all the federal states in the U.S.

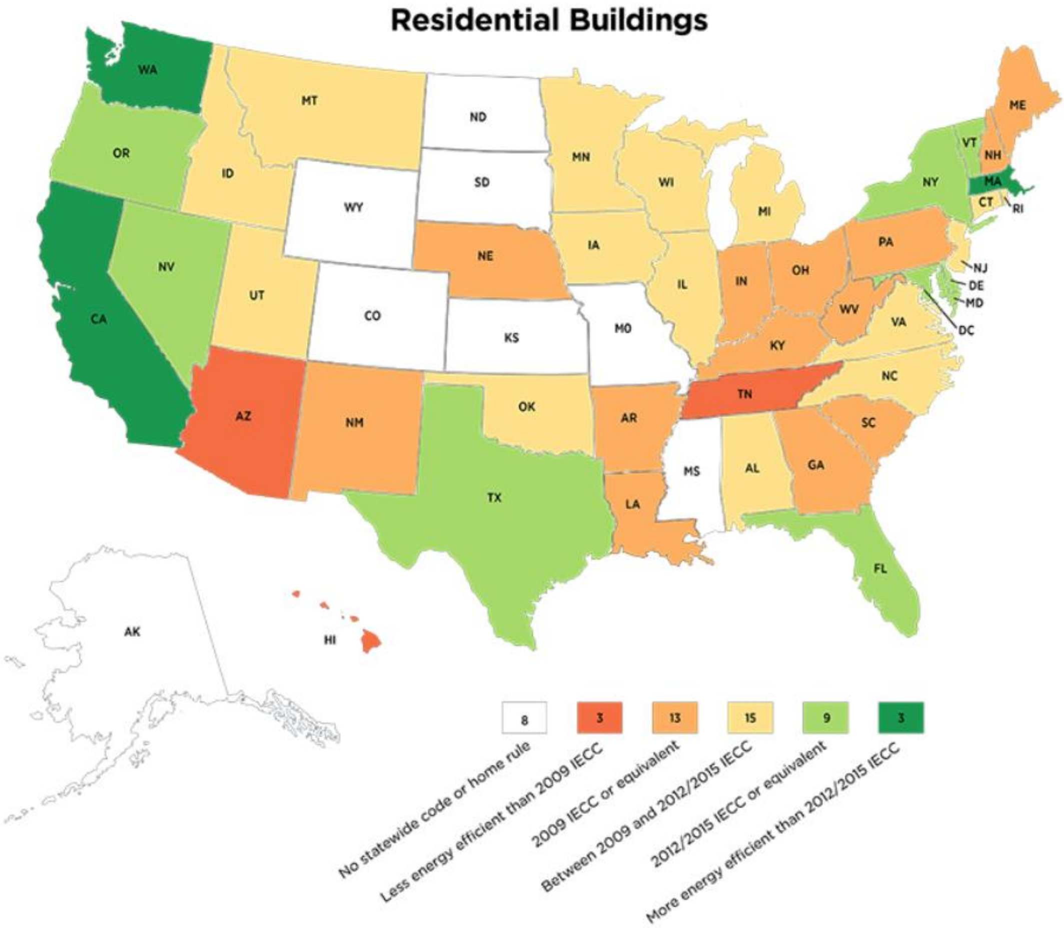

Figure 3.21 National Status of Residential Energy Codes Adoption, the U.S. (Updated as of 15th December 2017)[95]

3.5.3 Energy-saving labels for home appliances and standards

Efficiency standards of home appliances serve as one of the most effective policies to

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94 https://www.energycodes.gov/adoption/process

95 https://www.energycodes.gov/status-state-energy-code-adoption

improve residential energy efficiency and save energy bills, as well contribute to the reduction of greenhouse gas emissions.

Though appliances with high efficiency are usually more expensive to purchase, they could protect households against increases in energy prices, and would be an attractive selling point when they want to sell their properties (NREL 2000, p.6). Many actions have been developed and performed to improve the energy efficiency of home appliances, particular domestic electrical appliances, so as to help keep energy bills down and improve indoor comfort. These actions in different areas are based on a common principle: they must be economically viable and achieve energy savings, i.e. the efficiency improvement cost must be paid back in a reasonable time through the energy saved (Bertoldi 1997).

Germany (Localisation of EU standards)

EU Directive 92/75/EC[96] established an energy consumption labelling scheme, which identifies the energy efficiency of home appliances powered by electricity, gas or oil. EU energy labels are separated into at least four categories:

- The detail information of appliances, e.g., models, materials etc..
- Seven colour-differentiated energy classes: a colour code associated to a letter, i.e. from the top efficient category “A” in dark green to the least efficient category “G” in red, or from the top efficient category “A+++” in dark green to the least efficient category “D” in red.
- Consumption, efficiency and capacity of appliances.
- Noise, which is emitted by the appliances.

Energy labels must be clearly displayed on the offered electronic products for sale or rent. In addition, on 21st October 2009 European Parliament and European Council established a framework for the setting of eco-design requirement for energy-related products sold in all 28 Member countries. Ecodesign Directive[97] covers more than 40 product groups, which include not only household appliances also energy-related elements such as windows, insulation materials etc. If the energy labels aim to help consumers save energy by purchasing and using of appliances, the Ecodesign then aims to require that manufacturers

[96] European Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances. Directive 92/75/EC was replaced by Directive 2010/30/EU that must be applied from 31 July 2011. (http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31992L0075)

[97] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0125

are obliged to reduce energy consumption and other negative environmental impacts of products at the design stage[98]. Both energy labelling and Ecodesign help eliminate the least performing products from the market and contributing to the EU's 2020 energy saving targets significantly. As of 26th September 2015, in Germany all new heating appliances, hot water tanks and water heaters are required to display the EU Energy Efficiency Label.

Since European legislation must be transformed into national legislation within a given period, the German government has drafted the Energy Consumption Labelling Act (EnVKG)[99] and the Energy Consumption Labelling Ordinance (EnVKV)[100] into its legal system. The energy efficiency of household appliances sold in the German market is identified with EU energy labels. In addition, Germany rolled out a new efficiency label from 1st January 2016, which applies to all boilers that are more than 15 years old, so as to inform consumers about their boilers' efficiency rating and to provide current available products and services with higher efficiency, and ultimately to encourage consumers to equip their residential units with higher energy-efficient equipment.

China

In August 2004, the National Development & Reform Commission of China and the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ) jointly developed and issued "Energy Efficiency Labelling Management Approach", which marks the implementation of China's energy efficiency labelling system. The China Energy Label (CEL)[101] compulsorily implemented since 1st September 2008 is an energy efficiency index for most household appliances in China (e.g., monitors, LCD TVs, plasma TVs, cookers, washing machines, refrigerators, water heaters, energy saving lamps, printers, copiers, fans and air conditioners etc.). The CELs of products provide the information that is displayed on products, including,

- Producer name or abbreviation.

- Product models including performance indicators.

- Energy efficiency rating, i.e. the products' energy efficiency class from top efficient category one to least efficient category five and differentiated by colours from green to red.

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98 http://ec.europa.eu/growth/industry/sustainability/ecodesign_de

99 The German Energy Consumption Labelling Act: Energieverbrauchskennzeichnungsgesetz (EnVKG)

100 The German Energy Consumption Labelling Ordinance: Energieverbrauchskennzeichnungsverordnung (EnVKV)

101 The China Energy Label System: http://www.energylabel.gov.cn/index.htm

- Energy consumption index or efficiency indicators.
- Energy efficiency number based on the national standard.
- And energy efficiency information code.

USA

The U.S. Department of Energy Building Energy Codes Program (BECP) periodically evaluate national and state-level impacts associated with energy codes in residential and commercial buildings. It aims to find out to which extent the energy consumption and cost can be saved and CO_2 can be reduced under the effect of implementing the energy codes, in form of annual or cumulative savings (Athalye et al. 2016). The American Building Technologies Office (BTO) implements minimum energy conservation standards for more than 60 categories of appliances and equipment covering about 90% of household products in residential units[102]. The Energy Star Label in the U.S. as a green sticker provides simple, credible, and unbiased information for consumers and is mandated implemented in major household appliances and equipment.

The critical function of energy conservation labels on household appliances and equipment in different countries is to convey important energy-saving information intuitively and as exhaustive as possible, in a way of comparison or endorsement, as well how to use it effectively, so as to help consumers identify the potential benefits out of the additional costs. Many studies on energy efficiency policy for residential sector until recent mainly focused on revising the existing regulation or clauses after the deficiencies arose and even only for these arising problems. Therefore, energy performance policies need an innovation system, as which are needed for households with varying socio-economic background. It is noteworthy that any change in energy efficiency produced by political measures will affect the amendment and implementation of policy in turn, which highlights that effective energy policies are crucial to increase energy saving awareness and change behaviours among all the actors. Therefore, based on the empirical study for preventative measures and effective resolutions, the future research must be established with the participation of all stakeholders (Beerepoot and Beerepoot 2007).

In Summary, an energy-effective operation of residential buildings depends on four main aspects generally:

- Ensuring the supply of housing for requesters of all social strata.

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[102] https://energy.gov/eere/buildings/appliance-and-equipment-standards-program

- Guaranteeing housing quality under the rational design and configuration.

- Developing a sustainable concept to manage the energy supply and consumption in residential buildings or housing.

- Improving energy-conserving awareness and behaviour of occupants.

The first aspect is the main responsibility of housing policymakers who decide investment for residential buildings and corresponded allocation, as well influence the house prices to some degree. Architects and civil engineers take the second part, as their contribution is crucial for the success of investment by decision-makers or private housing owners, and can guarantee an effective building operation once the residential construction put into use. As the core of energy efficiency in the residential sector, the third part intends to ensure a continuously efficient operation during the service life of buildings and appliances and equipment, which is the primary work of building managers and energy providers who are in charge of making the building operation smoothly against any errors. Residential buildings need be equipped to measure, monitor and record energy consumption data for each energy source and end-use category and transfer them to management centre immediately, which are the basic work task of building managers and energy providers. Aiming to achieve bilateral energy efficiency, namely energy conservation on sides of suppliers and users, building managers and energy providers have to be responsible to draw up optimized energy management scheme or modes for suppliers after collecting and analyzing consumption data, therefore the necessary energy-saving advices and services could be provided to users. Building managers and energy providers never work separately or independently, if successful business models are expected for the future market of efficient energy management in the residential sector. An effective cooperation among the first three aspects ensures a well-operated residential energy system with efficiency, sustainability and good cost-benefit-rate. However, the last aspect, also various energy-using behaviours of occupants, influence the final energy consumption and indoor environmental quality largely.

3.6 Improvement potential

A valuable, if not only quantitatively measurable, contribution to a rational use of residential energy arises through a good interaction of both occupants' intervention and technical operation of building energy system. A proactive involvement of occupants, particular for people who prefer to build or update houses by themselves, from the selection of architects for designing and planning, and up to the partial self-administration of the house, is decisive to explore more energy saving potentials. This interaction ensures a sustainable use of residential building over a longer time and could even reduce or avoid cost- and energy-intensive retrofitting (Gonzalo and Habermann 2006, p.56).

3.6.1 Technological improvement potential

The typical technological shortages resulting in energy loss in residential buildings refer normally to envelope leakage and inefficient ventilation, as well failing to take the advantage of solar energy, which is regarded as a kind of passive-energy-loss. Residential building energy system is developed and optimized following the strategy of „Building tighter, ventilation better, and sunshine more“. Although many energy-efficient technologies are proven effective and technically feasible for residential buildings, their integration and operation as part of building energy system are not well understood, so that the installed energy equipment is not used as efficiently as possible. Therefore, it has to be identified firstly the influencing factors that could be affected in the initial phase of architecture and engineering engagement, so as to find those challenges and explore the energy-saving potentials. Except the framework conditions mentioned in chapter 3.2, there are still some factors influencing energy consumption, particularly by the case of dwelling stocks:

- **Number of storeys**. Increasing the number of storeys of residential building can reduce the average energy consumption per m^2 or ft^2 to certain extent.

- **Room arrangement**. The room arrangement was proven as a very important factor for architectural energy efficiency (Nasrollahi et al. 2013, p.34). In general, rooms with high occupancy rate during the day are arranged in direction of South for more daylighting and solar energy extraction, such as living room, kitchen and eating room, which contributes to energy saving and enough ventilation and sunshine for health. Bathroom or storage room as the ancillary space for short periods can be located towards North, but have to be well ventilated naturally or mechanically. Rooms oriented towards West are not suggested for the living room and bedroom in the zone with hot summer, for avoiding the scorching sunshine in the afternoon. Except for the intervention of architectural design, arrangement of rooms in dwelling/house is affected by occupants’ preferences too.

- **House with green roof**. In some dry and hot climate zone, a green roof can significantly reduce house cooling costs and GHG along with artistic landscape.

3.6.2 Low-energy house (Germany, China, USA)

An inevitable conflict between indoor comfort and energy conservation is all along a traditional perspective. Both pursuits are influenced and restricted with each other, particularly for most conventional residential buildings. For these reasons, energy efficient buildings have developed in different forms since a few decades, such as passive house, active house, zero-energy buildings or energy-plus buildings. They are designed in energy-conserved architectural form, with energy-saving materials, and through drawing support from renewable energy sources. From the view of building technology low-energy buildings typically use high level of insulation, two or three-pane glass of window and insulated window frames, and relative low air infiltration rate, as well as heat recovery ventilation system, to eliminate energy for space heating and cooling. The term of "Low-energy house" has innovated over time und varies among different countries, and refers to both specified building energy standard for new construction and to staking a claim for energy-related refurbishment of existing building.

Germany

The "Low-energy house" construction has prevailed over the past twenty years in Germany. "Low-energy" construction is the goal of EnEV, which replaced the formally Heat Protection Ordinance 95 ("Wärmeschutzverordnung, WSVO 95") on 1st February 2002. In the context of residential buildings, low-energy house is defined as such a residential building type that energy consumption is considerably lower than the legally permissible values (e.g., required in EnEV 2007, 2009, 2014 and 2016 with increasingly restrictive energy-saving demand). Except two main limits defined by EnEV (primary energy requirement and the specific transmission heat loss of the building), low-energy house requires a holistic optimization within the building construction, for example,

- Orientation of the essential building areas to the South.
- Optimization of building geometry, e.g., zoning, if necessary.
- Opaque transmission surfaces (e.g., wall, roof, ground) with 20-40 cm insulation.
- Window with heat protection glazing and insulation frame (e.g., $U_w < 0{,}8$ $W/(m^2 \cdot K)$, g = 50-60%[103]).
- Minimizing thermal bridges.
- Fully using renewable energies, e.g., geothermal energy, solar energy with minimal shading.
- Ventilation system with highly efficient heat recovery of outlet air (Schulze-Darup 2009).

Passive house as a common type of low-energy house in Germany refers to a building

[103] Energy transmittance value (i.e. g-value), is a measure of the permeability of transparent components for energy. It specifies the percentage of the energy that can reach the interior through solar radiation and thus contribute to indoor heat gain.

construction standard that only a negligible heating energy is needed in the Central European climate and therefore any active heating supply is not necessary. Such low-energy house can then keep the expected indoor air temperature alone with internal heat gains (e.g., physical heat dissipation of occupants, dissipated heat of lighting and electrical appliance) and solar energy radiated through transparent building components (e.g., windows and glass doors) as well as heat recovery system (Feist 1992), thus means “passive”. Passive house building allows for space heating and cooling energy savings of up to 90% compared with conventional building stock and over 75% compared to average new buildings. Energy for space heating in such a passive house is less than 1.5 L/(m^2•a) of oil or 1.5 m^3/(m^2•a) of gas, which is substantially more energy-saving than common low-energy buildings. For the passive house complying with Germany or European standard, the annual heating energy may not exceed 15 kWh/(m^2•a) and the primary energy consumption shall not exceed 120 kWh/(m^2•a) for space heating, domestic hot water and electrical equipment and lighting.

(a)

(b)

Figure 3.22 Passive house in Germany. (a): the first passive house in the world in Darmstadt-Kranichstein, (self-taken photo on site); (b): passive house WohnArt3 in Darmstadt[104], as social housing.

The heating energy consumption of the first passive house with four series units is an average of 10 kWh/(m²•a) and remained constant since then. Except for significant energy saving, this passive house provides high living comfort and without any "performance gap", which means there were no challenges to normal residents. Another is the passive social housing WohnArt3, which was built in 2009 in Darmstadt. Its energy consumption for heating and domestic hot water in 2011 accounted for 41.4 kWh/(m^2•a), this value was about 69% lower than the German actual average of 133.0 kWh/(m^2•a) in 2011 (referring to research in aFTeR Project[105]).

Passive house put environmental protection and energy saving front and centre, but not everyone will take it as value. As passive house pursues a significant reduction of heating energy owing to the high airtightness, which means it is at the expense of sufficient or necessary ventilation, and therefore results in a risk of muddy indoor air. Another complaint from occupants in the passive house is that it is difficult to provide highest indoor comfort for all rooms, in particular the indoor temperature in winter, which is possibly caused by the uniform heat supply through passive system combining with different heat gain from solar radiation due to room orientation.

Under these circumstances, active housing as an emerging design of residential building has been developed as an evolution of the passive house philosophy and has been popular in Germany since a few years ago. Except for the advantage of passive house, active house adds comfort as a vital priority that makes it more attractive and marketable. In other words, an active house should be low energy, low emission or pollution, and great to live in as well. Active house concept indicates that indoor required energy is produced either through the environment or in conjunction with mechanical devices (e.g., heat pump, energy storage) to utilize renewable energy for space heating and cooling (Wachenfeldt and Bell 2003), which determines that it puts forward higher requirements on local condition and building orientation. The notable advantage of active house reflects particularly in its use of natural light and ventilation. However, in most cases, active house needs extra external energy to offset the inevitable thermal loss during practical ventilation that it might consume more energy in quantity than passive house.

Two points are essential to be considered during designing and operating passive/active buildings. One is the room allocation during the design process by architecture, it is suggested that the infrequently occupied rooms can be allocated towards east or north due to less requirement of sunshine or high indoor temperature, such as storage room, bathroom,

[104] http://www.passivhausprojekte.de/#d_1559

[105] https://ec.europa.eu/energy/intelligent/projects/en/projects/after

on the contrary, the child room or sitting room where receive more natural light and sunshine towards south side. Another noteworthy feature is to make sure that occupants behave as they are expected, otherwise, the benefit of passive/active design will be discounted largely.

China

China has still not exactly Zero Energy Building program. However, Chinese government (i.e. MOHURD) has made significant efforts to develop national or regional green building standards, which define the energy efficiency requirements on residential and commercial buildings located in different climate zones. For example, the Three Star System developed by MOHURD works as a standard mainly for evaluating large residential buildings and public buildings, which has developed with learning from the successes and experiences of LEED in the U.S. and some European Standards of Low-Energy Buildings. This evaluation system focuses on mainly six assessment aspects (Zhou 2014):

- Land saving and outdoor environment.
- Energy saving and energy utilization.
- Water saving and water resource utilization.
- Material saving and material resource utilization.
- Indoor environment quality.
- Operation management.

Comparing with the relevant standards and requirement, the Three Star System in China on the one hand, seems too general or vague to be taken for practical cases, meanwhile makes it difficult to achieve fair and accurate evaluation results. On the other hand, Three Star System is lacking sufficient and comprehensive assessment schemes that can meet energy efficiency in new building and a large quantity of existing residential buildings in China. The assessment mechanism of Three Star System is still based on the simple accumulation of scores that are cumulated through reaching the requirement of assessment item rather than a weighted scorning system, therefore some developers prefer to applying simple and cheap green technologies instead of sophisticated and more efficient but expensive technologies (Geng et al. 2012), aiming for being accredited.

USA

Except for before mentioned LEED program, there is another certification program for low-energy building design in the U.S., the EPA's ENERGY STAR[106]. ENERGY STAR is a technical assistance and recognition program that defines the energy efficiency requirements on the thermal enclosure system (e.g., air infiltration rate, primary insulation levels, and primary window efficiency), heating and cooling system (e.g., total duct leakage, duck leakage to outdoors, primary heating and cooling characteristics like system type, fuel type and efficiency), water management system (e.g., flashing, drainage plan, water-resistant materials, control of moisture levels during construction), as well as lighting and electrical appliances (e.g., ENERGY STAR qualified lighting and appliances and fans, as well as type and efficiency of water heater) in an ENERGY STAR certified home. Properties with ENERGY STAR certification consume about 35% less energy than their non-ENERGY STAR counterparts.

Although both certifications (i.e. LEED and ENERGY STAR) promote higher energy efficiency in buildings, LEED works as a broader certification for environmental friendly green buildings, while does not necessarily guarantee energy efficiency. In comparison, ENERGY STAR takes energy efficiency as the first step to green, and all green properties should be energy efficiency. Due to these differences, it is hard to directly compare both programs regarding their financial costs and benefits, which might depend on an individual project's specifics. Taking the environmental protection as a primary consideration, it appears that the LEED certification may be generally difficult to obtain than ENERGY STAR certification (Hansen 2014).

For the past few years, net-zero energy home has become popular in the U.S., particularly in California. According to the survey from the Net-Zero Energy Coalition, California is home to more than half of all the net-zero buildings in the U.S. As one type of energy-efficient buildings, net-zero energy homes requires that the actual annual delivered energy is less than or equal to the low-cost, nonpolluting and on-site renewable exported energy (Peterson et al. 2015). In other words, the net-zero building designers combine efficient building construction, efficient energy-related equipment and appliances and lighting, and passive and active energy system (e.g., solar system, earth cooling tubes, geothermal heat pump, power grid for storage etc.), to reach the zero energy consumption goal.

However, net-zero energy homes in the U.S. have also its limitations. For example, it is more suitable for single family house than mid- or high-rise residential buildings to utilize solar energy as a major renewable energy supply. Therefore, how to achieve the feasibility and replicability of net-zero energy residential buildings from a technical, financial and market perspective, is still a matter to be handled by different stakeholders.

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[106] ENERGY STAR is a U.S. Environmental Protection Agency (EPA) voluntary program that helps business and individuals save money and protect climate through superior energy efficiency, referring mainly to buildings (e.g., residential, commercial and public) and products (e.g., energy-related appliances, and building materials). https://www.energystar.gov/

Except the original design and performances of building construction and energy-related facilities, the frequency and level of maintenance play a considerable role in building energy efficiency in the long term. A good building maintenance should require a regular maintenance of building elements, energy system and air quality systems including cleaning furniture and duct, etc. (Alvarez et al. 1996, p.14).

3.6.3 Possibility of social participation

If humans are intended as active energy users within different energy flows, the relevant energy policy could be better understood (Wilhite et al. 2001), in other words, energy supply and management should be viewed from an energy-user perspective (Lutzenhiser 2009, p.39). However, as energy is invisible, it is understandable that why so many people are not aware of how much energy they have consumed or whether they might have consumed much more than they really need.

It is crucial for building energy efficiency to make occupants understand and accept the energy saving measures suggested by experts, as well involve themselves in these measures actively with the increasing awareness of energy conservation, otherwise, it could result in impeding the expected control and management of energy consumption (Mitterer et al. 2012, p.230). Many studies (Chen et al. 2011, Hunter 2004, Tindall et al. 2003) have corroborated that occupants with high education or holding more knowledge about energy conservation in hand have higher intention to conserve energy, as well could be keener to perceive their energy using behaviours and engage in conservative behaviours. In the study by Bartusch (Bartusch et al. 2012, p.642), it was found out that many of the independent variables (e.g., outdoor temperature, building properties and energy-consuming installations) failed to demonstrate any statistically significant differences in annual electricity consumption per square meter heated living space. The most likely underlying reason might be the impact of individual household energy-related behaviour, which could affect the final energy consumption significantly. According to research results by Lindén (Lindén et al. 2005), household energy consumption accounted for a fifth of the total in North European Nations and about two-thirds of all the energy use in the U.S. (Ewing and Rong 2008), patterns of occupant behaviour may influence levels of energy use to the same extent by choosing equipment and appliances. Therefore, combining with addressing energy conservation behaviour of occupants rather than merely focusing on price mechanisms or new technologies for curtailing energy consumption is an essential part of the success of sustainable residential energy efficiency.

An effective performance of residential energy conservation measures and energy policy needs a positive and active participation of occupants, as it determines to what extent the technological, political and economic contribution are accepted and implemented by end users, and also affects the level of behaviour change and awareness improvement of occupants. Meanwhile, social participation also depends to a certain extent on the availability of technology and information, on reasonable and political programs supporting the residential energy conservation. For instance, instead of expensive energy efficient retrofit or appliances paid by consumers it is more acceptable to provide educational programs for those limited-resources consumers with low- and no-cost ways to reduce energy costs, thereby increasing the likelihood of future investments in energy conserving retrofits.

Aiming to improve social participation of occupants in energy saving activities, it is worth to keep in mind by housing designers and operators that the most significant resource for an efficient residential energy consuming system is its consumers, i.e. occupants. Each effort should not forget to educate and encourage the occupants to take full advantage of the sustainable management and services and behave with better energy-saving awareness. Many studies indicate that the informed, concerned and proactive occupants are necessary to pull the energy market towards a greater efficiency (Boardman 2004). On the contrary, a poor social participation causes not only a waste of resources and investments but also a possible change in energy policies and incentives that ought to have benefited the consumers and other stakeholders. The reasons resulting in weak social participation are many-fold due to different objective conditions, but some of them are common, for example, insufficient energy saving awareness of occupants owing to living tradition and habits, and organization failure of building owners and energy managers. Therefore, sufficient energy-saving knowledge and information are continuously necessary to incentivise the public.

An effective measure promoting to improve social participation, i.e. improvement of energy efficiency in residential buildings by subjective initiative, has to recognize the individual characteristics of energy consumers, such as their culture and tradition, attitudes to household energy use and driving forces behind their actions and changes, household demographics and income levels. Bin and Dowlatabadi introduced the Consumer Lifestyle Approach (CLA) to postulate that five factors determine consumer use behaviours and consequences (Bin and Dowlatabadi 2005):

- External environmental factors (e.g., culture or family background) from the con text in which consumer decision processes happen.

- Individual determinants (e.g., personal attitudes).

- Household demographics (e.g., single-family, family with/without children, or multi-generation family).

- consumer choice or action.

- Natural environmental impacts (e.g., climate or geographic conditions). (Guin and Kirby 2013).

In occupant behaviour research at Lawrence Berkeley National Laboratory Building

Technology and Urban Systems (LBNL BTUS) conducted by Tianzhen Hong and his team, it introduces a DNAS (Drivers-Needs-Actions-Systems) ontology for occupant behaviour standardization[107]. This ontology addresses especially the influence the factors of energy-related behaviour of occupants:

- **Drivers** represent the environmental factors that stimulate occupants to fulfil a physical, physiological or psychological needs.

- **Needs** mean the physical and non-physical requirements of the occupant that must be met in order to ensure satisfaction with their environment.

- **Actions** address the interactions with systems and activities that occupants can perform a achieve environmental comfort.

- **Systems** refer to the equipment or mechanisms within the building with which occupants may interact with to restore or maintain environmental comfort.

In addition, different methods and theories were developed to analyse occupant behaviours from the socio-culture and socio-economic perspectives. Frederiks (2014) introduced a "behaviour economics" theory that focuses on what we shall do to bridge the gap between knowledge/awareness and actions. Røpke (1999) indicated that change of behaviour and therefore the resulted change of living requirements and qualities could be understood as a consequence of societal processes, which have been described as drivers behind quantitate energy consumption of households. Gram-Hanssen (2011) also considered that there could be an interaction between energy efficiency and consumer behaviour, which includes psychological and social understanding more than pure economic and technological factors. Wilson and Dowlatabadi (2007) promoted the relevant theories that determine occupant decision-making with regard to residential energy use, e.g., utility-based decision models and attitude-based decision models. The utility theory of decision-making is based on economic theory, i.e. it is assumed that occupants make behavioural decisions "rationally" for maximization of the performance of utility given budget constraints like household income and preferences and prices of goods (Damton 2008, Jackson 2005). The attitude theory of decision-making, however, is more vulnerable than utility-based, as it is influenced by different common and individual factors, such as the attributes and description of technology and practice, knowledge and experience of new energy-efficient products, and individual interests and habits. Both theories are developed from the perspective of energy-related purchase phase. Moezzi and Lutzenhiser (2010) highlighted in their theories the impact of occupants on residential energy consumption and pointed out the shortcomings of some old ideas and theories that have analysed how

[107] https://behavior.lbl.gov/?q=node/2

to improve building energy efficiency. For example, some thought technology and behaviour as two separate realms, which might lead to mismatches between invested technologies and policies with the real usage by occupants. Wood (2006) found out in his study that the way people really use thermostats at home may be much different than assumed in current codes and models or in designing process, as households are much more active to manage their internal temperature through using the thermostats more sophistically than has previously been supposed in models, even if thermostats have already been developed to a very intelligent level. In addition, the Theory of Planned Behaviour (TPB) (Ajzen 1991) proposes that human behaviour is resulted from the initial human intention that essentially influenced by human's concerns or attitudes towards the behaviour, subjective norms and values, and perceived behavioural control. TPB is extended to the field of household energy use (Clemet et al. 2014) for prediction of energy conservation intentions and behaviours at home. Though TPB identifies a relative clear thought about the causal association among behaviours and the underlying foundations, however, an exact form of these relations is still uncertain and the corresponding research and application in residential energy conservation are also inadequate, moreover TPB has problems to explain repetitive occupant behaviours (Klöckner 2013).

For the current situation, the social participation is challenged by the following aspects:

- Accessible information and technologies.
- Adaptable and optional technical equipment.
- Acceptable prices for optimal qualities.
- Improved living comfort and safety.
- Trade-off analysis among stakeholders.

It is worth to mention that the trade-off between the immediate costs of the investment and savings expected in the medium to long-term could be a major barrier to energy efficiency investment (UNEP SBCI 2009). The immediate costs of the investments refers not only to the monetary costs for implementing energy efficient measures (e.g., retrofit, refurbish, replace and moderate for existing buildings, or high-efficient technologies in new buildings), namely "the first cost", but also to the necessary changes in living customs that sometimes is a challenge for the households. For instance, some studies have found a linear relationship between energy demand for space heating and indoor temperature, however which is often different for various types of buildings and heating systems due to preferences and consumer behaviour (Leth-Petersen and Togeby. 2001, pp.387-403). It might also depend on the building thermal quality and the climate (Haas et al. 1998, pp.195-205).

3.6.4 System and institutional challenges

For starting and operating an entire system efficiently, the strong support from public bodies to provide an effective legislation and funding, and the updated building standards are necessary. A proactive motivation to strength occupants energy-saving awareness and thus to change their energy-related behaviour is hard to be achieved without initiatives from communities and authorities. Especially for low-income households, they cannot benefit from a proper organizational structure providing affordable living spaces and adequate financial subsidies. Feeding information to occupants could contribute to behaviour change, but only if information is accompanied by incentives and empowerment. Unclear legislation on the rights and responsibilities of related stakeholders and lack of revised criteria and indicators to evaluate energy performance could cause additional difficulties by gauging the savings derived from energy efficiency improvements, and thereby hampering an effective residential energy management and implementation of new technologies. In many cases, low participation of occupants is largely as a result of insufficient information and imperfect system, and in turn results in further inadequate trust and transparency.

In addition, the system challenge concerns about the fractional benefit clusters, as buildings have a long life cycle interacting with many different stakeholders. Especially for residential sector, the diversity and stochasticity of stakeholders' expectation and acceptable costs are much higher than commercial or public building system, and thus imperceptibly increase the difficulties of the research work and reduce the accuracy of the research results. Any decision by different stakeholders is possible to affect the energy consumption and the benefits of others.

3.6.5 Financial challenges (Germany, EU, China, USA)

Lack of sufficient financing is not only a normal obstacle for public bodies, but also the main worry of individual households that intend to improve home energy efficiency, no matter by retrofitting existing residential units or building new ones. It is particularly difficult for low-income households in social housings.

Most projects for improving energy efficiency of social housings require considerable financial support from government and builders and contractors, and the payback periods are much longer than other residential buildings at market prices so that these initiatives seem often unprofitable and less attractive. In this respect, different financial instruments are imperative for residential building renovation or modernization programs, which may differ dramatically because of the specific situation regarding technological requirements, economical availability, fluctuation of energy prices and the expected return of investment (ROI).

Germany

Financial subsidies are provided to households who plan to renovate their own home. This financial support can be used as a one-time payment or, in many cases, as a low-interest loan. The German Federal Office for Economic Affairs and Export Control[108] (BAFA) is responsible for energetic renovation with renewable energy sources, while the German Reconstruction Credit Institute[109] (KfW Bankengruppe) deals with all other building renovation projects and new energy efficient houses. KfW offers a wide range of programs for financial investments in real estate in the areas of residential energy efficiency. The purpose of these investments is to make the residential properties, which are mainly for self-occupation instead of rent, more energy efficiency through different programs, such as energetic building renovation, housing modernization, new energy-efficient housing or converting the heating system to renewable energies like photovoltaic plant, biomass plant and heat pump. KfW promotional Bank as the largest business unit of the group contributes mostly to housing and environmental protection in Germany, and it is especially active in promoting energy-efficient housing for owner-occupied houses as well as for property owners, both for new houses and refurbishments of existing houses. The amount of the subsidies by KfW depends on the requirements on energy efficiency of housing/building, therefore KfW introduces the term "Efficiency House" with different energy-efficient levels, as Table 3.9 lists.

Table 3.9 Permissible peak values refer to EnEV Reference House

Standard	Primary energy demand	Heat transmission loss
Energy House 40	40%	55%
Energy House 55	55%	70%
Energy House 70	70%	85%
Energy House 85	85%	100%
Energy House 100	100%	115%
Energy House 115	115%	130%
Energy House Monument	160%	175%

Source: www.kfw.de (Last updated: December 2015)

Except for KfW, each Federal State of Germany has developed the respective subsidies to optimize residential energy efficiency. These housing promotions are provided in different ways, like low-interest housing loans or grants. The allocation of these subsidies complies with specific conditions and restriction, for example, some subsides are only granted to families with children or with severely disabled persons, or to low-income households. Subsidy application must be submitted before the start of construction or the

[108] Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA.

[109] Kreditanstalt für Wiederaufbau, KfW Bankengruppe.

conclusion of purchase contract with the competent Regional State Bank (Landesbanken). Same like KfW its object is to increase the supply of demand-oriented, low-cost and high-quality living space, and thus to reduce the residential energy consumption[110].

Europe

Financial instruments for supporting the improvement of the building energy performance in Europe are diverse and vary from country to country. Generally, all these financial or fiscal supports can be divided into two broad categories: conventional and innovative (Maio et al. 2012, p.8). Figure 3.23 shows the types of European financial support for energy efficiency of buildings.

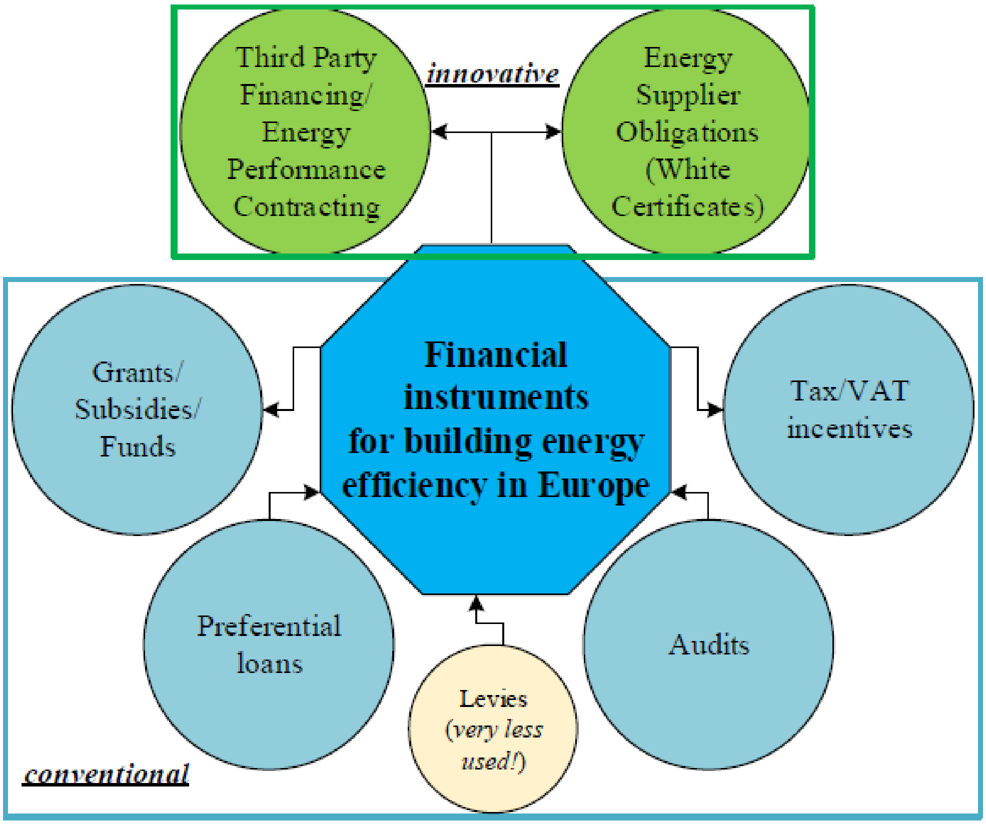


Figure 3.23 Financial support for building energy efficiency in Europe (Economidou 2011, p.90)

The varied financial programmes are implemented with different budgets under a wide range of duration from one year to decades. However, the key concern is the level of ambition that can be attained from the financial support, such as 10% saving, 30% saving, no or low energy consumption buildings etc., because it determines to which extent these financial instruments are suitable for optimizing building energy efficiency.

110 https://www.vergleich.de/wohnungsbaufoerderung.html

China

A very low civil energy price and relatively high upfront-costs for energy-efficient renovation, as well as potential post-costs for technical operation and maintenance dramatically hinder the process of improving residential energy efficiency in China, and currently the economic balance between saved energy and payback from the energy-related investment in China is still energy-price depended (Wang et al. 2015, p.120). Meanwhile, lack of sufficient capital for government and shortage of financial incentives for investors, as well as the incomplete energy performance contracting system create the effect of „adding insult to injury“ in urban residential sector undoubtedly, particularly in northern China where the heat energy is the main household energy consumption during long cold weather, while many dwelling stocks still are less-insulated. Moreover, many regions in North China have less developed economies and lower average household incomes than the regions in South China.

The financial support from central government prefers to release them to local governments in the ways of grants, reduction of value-added tax (VAT) and income tax, fixed asset investment tax exception or reduction, rather than directly to house buyer and owners. Based on local economic and social development, the support is allocated further by local government to real estate developers, project owners/investors, contractors, energy efficiency technology developers and renewable energy material manufactures (Li and Griebhaber 2013, p.18). For new buildings (commercial and public buildings also involved), the governments have promulgated a series of tax-based incentive policies for promoting their energy efficiency since the beginning of 1990s. For example, the Provisional Rules on Adjustment Tax for Fixed Asset Investment, which stipulated a tax rate of zero for fixed asset investment in energy-efficient residential buildings in the northern areas. In order to encourage the production and use of new energy-saving wall material with higher insulation level, a rational exception or reduction of VAT was issued by governments to benefit material manufactures (BECON-2009 Source, cited in Shui and Li 2012, p.38).

For the existing residential buildings, Chinese government puts the focus on retrofitting of residential buildings in northern severe cold and cold zones with a multi-source financing mechanism, as the deficiency of building/housing insulation in both two zones caused much more household heating energy consumption than in the regions of many developed countries in the same climate zones. During the 11th Five-Years-Plan (2006-2010) period, RMB 24.4 billion of financial support was arranged by the central government to retrofit residential buildings in northern heating regions, of which RMB 4.6 billion came from the central government, RMB 9 billion from the local governments, and RMB 10.8 billion from other non-governmental financial sources. During the 12th Five-Years-Plan (2011-2015) period, the central government proposed further a „Award instead of Supplement“ approach in order to stimulate the retrofit of building energy efficiency. Precisely the central government provided subsidies of RMB 45/m^2 for cold zone and RMB 55/m^2

for severe cold zone to help complete the retrofit work of residential buildings in both zones[111]. In addition, subsidies from local governments are also encouraged by the central government, which means local governments can determine their financial support for residential building retrofit based on the consideration of the local economic situation and development plans, except for the subsidies from the central government. Another financial support model is set up from the Energy Performance Contracting (EPC) system, which incentives energy efficiency in building sector more effectively through a third party Energy Service Company (ESCO), i.e. government provides one-off grants to ESCO if they can achieve the beforehand required energy saving goals, meanwhile government provides also exceptions and reductions of VAT, business tax and enterprise income tax to ESCO (Li and Griebhaber 2013, p.20).

Besides the national fiscal instruments, some international cooperation projects have been implemented to improve energy efficiency of Chinese existing residential buildings. For example, the cooperation project between the Chinese Ministry of Construction (MOC) with a German non-profit organisation GIZ[112] from November 2005 to October 2010. This cooperation project focused on retrofitting of residential buildings in three Chinese northern cities (Tangshan, Beijing and Urumqi) with targeted retrofitting concepts[113](Xu 2007). A Sino-Canada demonstration project of existing residential building retrofit in Harbin, Heilongjiang province were carried out in 1996-1999, which optimized the envelope and heating system for approx. 2442 m^2 of existing residential buildings (Zhao et al. 2006).

Despite those investments in energy efficiency of residential buildings, the results of an “Energy-saving survey” conducted MOC in 2005 showed that 74% of respondents could afford the 10% of retrofit costs, and only 6% of respondents would take more than 20% of the whole costs (REEEP Project - Progress Report 2009, p.8).

USA

The federal financial incentives for supporting building energy efficiency in the U.S. have been undertaken in different ways since a very long time, i.e. a set of tax incentives were available from 1978-1985. For residential sector, some financial programs were carried out mainly in the forms of grants, loan guarantee, end-user investment tax credit for primary residents and high-efficiency home equipment, as well as personal tax exemption and personal tax credit. These tax credits are based on building energy performance measured by ft^2 and level of achieved sustainability, which refers to a minimum energy reduc-

[111] http://jjs.mof.gov.cn/zhengwuxinxi/lingdaojianghua/201107/t20110714_576304.html

[112] Deutsche Gesellschaft für Technische Zusammenarbeit

[113] www.eeeb.org.cn

tion of 10% for building retrofits or new home construction, and 25% reduction for lighting upgrades. Besides making building construction more efficient, some financial policies are targeted to encourage residents to buy energy-saving appliances at a tax-free or -reduction prices. For example, Missouri offers an occasional sales tax holiday on the purchase of ENERGY STAR appliances, and in New York there are special financial incentives and technical assistance to owners of multi-family buildings to improve their building energy efficiency (Doris et al. 2009, pp.15-17).

In addition, local governments of the U.S. provide the municipal bonds for improving residential energy efficiency. This financing specifies and ensures the benefits of homeowners relative clearly, which means, homeowners do not have to recoup their investment through home sale price by changing home ownership as the loan resides with the property owners rather than the purchasers (Doris et al. 2009, p.18).

All the financial incentives and programs for optimizing building energy efficiency carried out by the U.S. government also aim to educate the public on benefits of energy efficiency and increase market penetration of existing energy efficient technologies, which are beyond merely saving energy consumption, but rather increasing the number of "green jobs" by expanding the market for energy audits and efficiency retrofits (Doris et al. 2009, p.15 and 18).

3.6.6 Rebound effect

Baker and Standeven (1996) have claimed that occupants behaviours have potential to reduce energy demand for room heating and cooling by adjusting the requirements on indoor thermal condition, given the access to manual control of indoor environment appliances. However, many investigations have reflected the unexpected gap between calculated and real energy consumption, for example, in some extreme case with 300% gap (Marchio and Rabl 1991, Emery and Kippenhan 2006). In particular, the reduction of energy consumption in the high-income household group seems significantly lower than expected or calculated, albeit those households undoubtedly can afford the additional investment on retrofit and information for home energy saving. From an economic perspective, this could be identified as "Rebound effect" (RE), as equation 3-5 indicated. Increasingly efficient energy products reduce the relative price of energy in a disguised form, thereby it encourages households to equip their residential units with more appliances and inhabit in houses with growing floor area, which thus increases the total energy consumption with the same services, even though with more efficient energy technologies, as illustrated in Fig. 3.24. Rebound effect is reflected in residential energy efficiency as an adverse impact of lower costs of energy services on occupant behaviour and attitudes towards building energy efficiency (EEA Technical Report 2013).

$$\text{Rebound effect (\%)} = (\text{Calculated Savings} - \text{Actual Savings}) \cdot 100/\text{Calculated Savings} \quad (3\text{-}5)$$

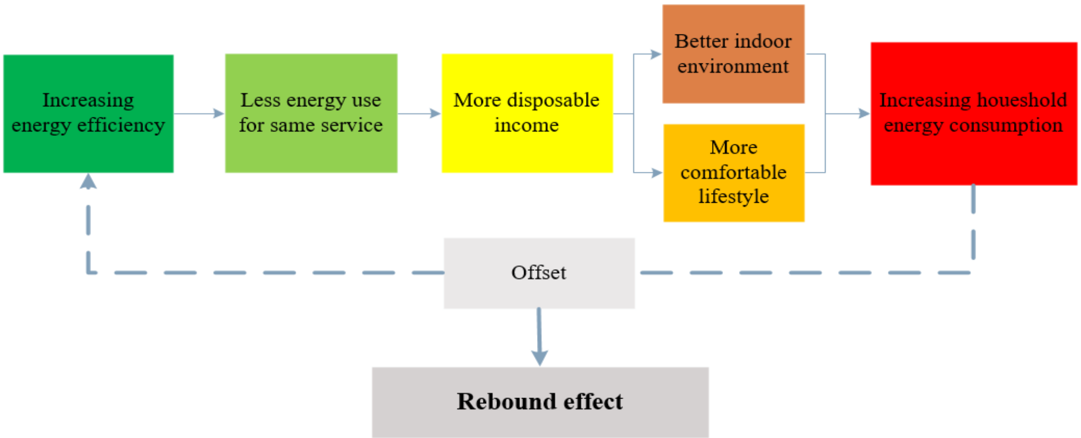


Figure 3.24 Rebound effect of household energy efficiency

Rebound effect within household sector appears not only in developing countries (Ouyang et al. 2010) where a relative higher economic increase stimulates occupants to consume much more energy than they real demand, but also in developed countries (Hong et al. 2006, Milne and Boardman 2000) where is with relative stabile economics. According to a review of empirical estimation, the rebound effect of private heating energy consumption is approx. 20% (Sorrel et al. 2009). Cararo et al. found out in their research on heating energy consumption in German households that buildings retrofits improve the energetic standard of buildings and heating system indeed, unfortunately the households may change their behaviour from the previous relative „energy-frugal" to „energy-squandering" as energy services were getting cheaper and thus increased the absolute energy consumption (Cararo et al. 2011).

Serious rebound effect appears in particular household electricity consumption. Because heating consumption seems to depend on the thermal efficiency of buildings to a greater extent, whereas household electricity consumption depends on much on occupant behaviour. Therefore, it could not explain rebound effect of household energy consumption only from an economic understanding, but rather should also take the impacts of the awareness and behaviour into account.

Because of rebound effect the quantitative increase counterbalances the energy efficiency gains from qualitative optimization to a certain extent. Another noteworthy point is that rebound effect is indirect in most cases, which means, more energy input for an energy-efficient product than for a traditional one. For example, high efficient household appliances (e.g., dishwasher or laundry facilities) include normally more energetic efforts during a series of complex and elaborate production processes, in spite of an energy-saving operating process by end-users. Energy efficiency lowers the cost of unit energy so that we tend to use those so-called savings on more unnecessary activities or items that either use energy or have energy embedded in, as a result the rebound effect happens (Walsh 2010).

3.6.7 Other influencing factors

Except the main reasons introduced above, there are some other influencing factors that slow down or hinder to launch the energy efficiency concepts in residential buildings These factors cause diverse impacts on residential buildings located in different socio-economic and technical environment, for example,

- **Climate characters.** Climate has a major impact on the energy consumption in residential buildings and vice versa, residential energy consumption is a valuable place to start reducing emissions (Nelson et al. 2012). The relation between climate change and energy consumption in a certain region are investigated for explaining, analysing and even forecasting energy demand, and contributing to adapting power purchase contracts (refers mainly to gas and electricity for heating and appliances) under the influences of valid energy policies. Climate change resulting from energy consumption affects in turn energy consumption both short and long-term considerably. It has been proved to cause a greater change in peak demand than in total demand, which was particularly evaluated in electricity demand (EIA 2005, pp.55-58), because the final energy consumption for space heating and cooling is temperature-sensitive, particularly in residential buildings (Brown et al. 2014). Therefore, it has to take a correction factor corresponding to the deviation of the yearly HDDs and CDDs[114] into account before determining the energy consumption for space heating and cooling (Morović et al. 1987, p.80). The U.S. Environmental Protection Agency (EPA) concluded that climate change could cause a 14-23 per cent increase in electricity capacity additions between 2010 and 2055 in the total relevant sectors, relative to a future with no climate change (Brown et al. 2014). Impacts of climate change on energy consumption should be incorporated into regional energy system planning due to their different energy supply and distribution management as well as geographic variation, aiming to ensure an adequate energy supply and to meet peak demand (Marilyn et al. 2014). Lower outdoor temperature than usual in winter has an impact on the demand for space heating and thus on CO_2 emissions, the same happens in the regions with extra higher temperature in summer, where many electrical appliances are needed for room cooling, such as in the United States, part of China and some other south European regions.

- **Engel curve**, which describes how household expenditure on a particular good or service varies with household income (Chai 2010, p.1). It reflects in particular by the monetary allocation for energy efficiency investment in social housings. A limited household income prevents family members to invest more energy efficient products or services, even if they are willing to change their behaviour into

[114] http://www.degreedays.net/

an efficient way.

- **Energy prices**, which is one of the major influencing factors in how many energy household consumes and therefore how much energy-related CO_2 emission is emitted on average. In other words, prices affect the decision on changing their long-standing and poor efficient living styles. Nevertheless, energy is priced by government with taking full account of energy market and economic situation of countries or regions in a given period. Government can use energy tax policy, residential energy credit and carbon tax to influence energy prices and reinforce the value of the consumed energy unit. In a sense, energy efficiency is a policy domain.

- **Effects of payments and feedback on peak consumption**. Kohlenberg et al. and Hayes et al. have given their research results about the effects of payments, information, and feedback on peak consumption of electrical energy in private households, which showed that the greatest change in peak consumption occurred with feedback plus payment condition (Kohlenberg et al. 1976, Hayes et al. 1977). Palmer et al. have also proved that feedback and prompts to consumers were effective (Palmer et al. 1977).

It is noteworthy to mention that the largest potential of energy-conservation appears normally in middle-income households, while relatively less in high-income households who will not, and also in low-income households because they are not able to (Cunningham and Joseph 1978, p.201). In brief, all energy-related instruments (e.g., economic, administrative, informational instruments) and the physical instruments (e.g., energy price, household income, building structure, lifestyle etc.) interact with each other (Lindén and Carlsson-Kanyama 2002) and change energy efficiency in different households (Zhang 2004).

3.7 Conclusion

Energy saving measures refer to technologies and designs that improve building energy performance with less input. These measures consist of dependent and independent strategies, such as better insulation of building façade, high-efficiency glazing of windows, passive heating and cooling system, daylighting or energy-saving lights, high-efficiency HVAC and plumb technologies, integration of renewable energy, as well as smart metering.

As the foremost participant of residential buildings, occupants may not respond to the consumed energy immediately or correctly, but their individual behaviour influences this consumption directly and dramatically, also the indoor environmental quality. Gram-Hanssen stated in her research that the final energy consumption in households is affected and finally determined by the number/size of the technology, but the energy efficiency of the technology and the user practice have very close relation to and even influence the technology strongly (Gram-Hanssen 2011, p.992). According to the logic and strategies of California Residential Energy Efficiency Program (Lutzenhiser 2009, p.22), most factors affect occupant behaviour is indirect and mainly focus on individuals cognitive capability and awareness through a series of ways like access to energy-saving information by web audits, advertising, direct prizes and incentives, as well as price reduction and technical modernisation, so-called pre-action phase instead of action phase.

There is no silver bullet but a comprehensive multiplicity of actions to reach the targets of improving residential energy efficiency. Cross-functional interventions in a technical, economic, social and political way are pursued because it is crucial to understand the interaction between different intensives and barriers, which determine the residential energy efficiency as a whole and contribute to a suitable policy in this area. In particular, investing such efforts in social housings has the potential to optimize the living conditions for low-income households and relieve the stress of social housing supply on local government, as well to boost the local economy and ease the environmental worries. Meanwhile, improving energy efficiency in residential sector shall be not judged only by the monetary value, there are other important evaluation criteria like the optimization of living comfort and therefrom advances in health and living quality as a whole, as well ensuring more relaxed household fiscal allocation. To what extent could a good balance between benefits in energy consumption (or costs) saving and in comfort and health be achieved, depends on an exhaustive socio-economic analysis, which is particularly important for energy consumption in social housing buildings. (Clinch and Healy 2000, p.9).

In summary, there are five options that need collaboration with each other, so as to realize increase of residential building energy efficiency and reduction of greenhouse gas emissions:

- Reducing building energy consumption through technical refurbishments, which is based on well-designed building energy codes and standard.

- Integrating renewable energy or high-efficiency energy supply system into building energy system.

- Increasing penetration of energy-efficient household appliances.

- Improving energy-saving awareness of occupants and ensuring effective information transfer and exchange.

- Necessary and effective regulation and means for energy management in residential buildings.

4 Methodological analysis of residential energy efficiency

Methodological and simulation instruments are based on the choice and identification of relevant indicators that represent energy efficiency of building systems and indoor comfort. Retro-commissioning (RCx) provides a way to strategical optimization opportunities and tailored energy saving measures, which mainly contribute to improving the performance during the building operation phases and mitigating emergencies down the line for existing buildings, and doing upfront work with higher energy efficiency standard for new buildings. RCx identifies its ultimate purpose as optimization of energy efficiency in the field of building construction and energy systems with cost-effective solutions.

The International Performance Measurement & Verification Protocol (IPMVP) however can help stakeholders test the energy saving measures defined by RCx in quantity, because IPMVP defines standard terms and suggests best practice for quantifying the results of building energy efficiency with different separate approaches or combinations. The quantification process is brought out through Measurement & Verification (M&V Plan) of energy savings.

Occupant behaviour analysis demonstrates significant potential energy savings, which could explain why the technologies alone are unable to ensure an effective low energy use in residential buildings. The ontology DNAS (Drivers-Needs-Actions-Systems) (Hong et al. 2015) mentioned before formulates a cause-effect with the mutual influences of occupant behaviour and the inner and extern environment (e.g., energy-related individual internal requirements and common external stimulus).

In this Ph.D. research, an Integrated Retro-commissioning (IntRCx) is developed to analyse the combined impacts of technical conditions (objective or hard factors) and occupant behaviour (subjective or soft factors) on residential energy efficiency.

***Keywords of chapter 4*:**

Energy Efficiency Indicator, Retro-commissioning, International Performance Measurement & Verification Protocol (IPMVP), Drivers-Needs-Actions-Systems (DNAS), Integrated Retro-commissioning (IntRCx)

4.1 Energy efficiency indicators for residential building

Before introducing methodologies to analyse residential energy efficiency, it has to identify an evaluation instrument that assesses the effectiveness of any investment to improve energy performance of residential building. Indicators are understood in a sophisticated term as any of various statistical values that together provide an indication (IEA: Energy Efficiency Indicators-Fundamentals on Statistics 2014, p.17). Energy efficiency indicators as the evaluation instrument are developed normally in a broad range, defined at various levels based on the application coverage, i.e. at the level of an economic perspective, and of a service perspective or a mechanistic perspective, as well as of a sector (e.g. industrial sector, residential sector or transportation sector).

Energy efficiency indicators have multi-roles that serve, for example, as a monitor to observe the trends in energy efficiency and CO_2 abatement, as a comparison instrument to compare the energy efficiency performance level among countries or households. From the viewpoint of economy, energy efficiency indicators also reflect market penetration of energy-efficient technologies (e.g., proportion of energy equipment or appliances with green label, proportion of renewable energy for heating, cooling and warm water supplying), which serve as a complementary tool by evaluating the energy efficiency (Project: ODYSSEE-MURE EU-27).

The most contribution of energy efficiency indicators is the importance for policy makers to recognize both the weight of energy demand and the potential energy savings that could be achieved. Energy efficiency indicators not only report the real energy consumption, also provide the most insight into the underlying drivers that determine energy efficiency trends in the future. With regards to residential sector, energy efficiency indicators are able to explain the differences of energy-efficiency among households with the same energy-related equipment and under same geographic and climate condition, as well to address social inequalities in this sector. This could help the policymakers adapt their policy efforts and directions, as well design effective energy policies for residential buildings and track progress towards formulated policy objectives (Phylipsen 2010, p.5).

4.1.1 Identification of energy efficiency indicators

Energy-related data collection is the prerequisite to identify energy efficiency indicators. The scope and accuracy of collected data determine the accuracy of identified indicators In residential sector the collected data describe the characteristics of the main determining parameters (e.g., building construction, demographic traits of households, access to energy-related information and investment, climate and environment etc.). Generally, energy efficiency indicators are intensities, which present as a ratio between energy consumption (measured in energy units) and activity data (measured in physical units), as Equation 4-1 indicated (IEA: Energy Efficiency Indicators-Fundamentals on Statistics 2014, p.27):

$$\text{Energy efficiency indicator} = \text{Energy consumption/Activity data} \qquad (4\text{-}1)$$

In view of residential sector, energy consumption consists of energy for the end uses, such as space heating/cooling, room lighting, domestic hot water supply and for any daily life activity, aiming to meet living requirements and improve the satisfaction of occupants. Activity data, however, is introduced in such a sense that energy efficiency indicators are comparable in different space and time (e.g., square meters corresponding to space heating/cooling energy consumption, unit of household appliances corresponding to electricity consumption etc.). Different ways could be available for data collection and the most common are surveying (e.g. interview or questionnaires) and measuring on site (i.e. metering). Besides, modelling with the basic inputs (e.g., climate data in a certain long period, administrative sources and experience values) for prognoses are also feasible. Figure 4.1 depicts the common scope of data collected for developing energy efficiency indicators of residential buildings. Energy efficiency indicators of residential sector are computed normally at the end-use level. Certainly, the energy efficiency indicators of residential sector can be identified at different level except those in Fig. 4.1, for example, it could be more effective and economical with fuel use per dwelling or household instead of fuel use per capita for collecting consumption data of a residential building with large amount dwellings.

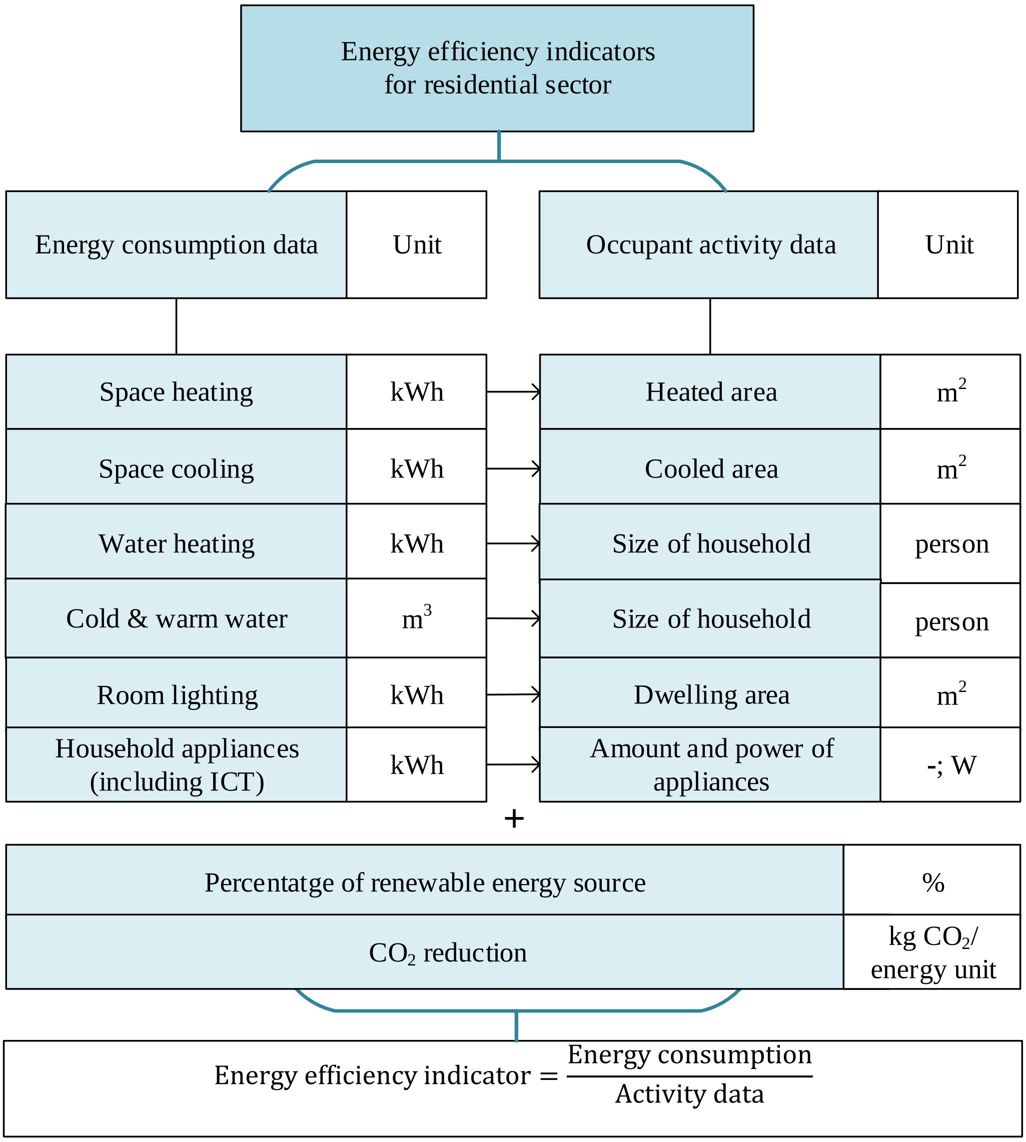


Figure 4.1 Breakdown of energy-related data for identification of energy efficiency indicators in residential sector

4.1.2 Development of energy efficiency indicators

Once a set of residential energy efficiency indicators is identified, the corresponding energy consumption data and occupant activity data need to be collected. It is very important to find an optimal approach to collect data, as data collection could be a costly task in time and money if an unsuitable strategy was chosen for some kind of data. IEA concludes the different methods used to collect energy consumption and activity data across end-use sectors like household energy consumption within the residential range. The detailed approaches and the corresponding strengths and weaknesses of them are listed in Table 4.1.

Table 4.1 Comparison of data collection approaches with Pros and Cons - Residential sector

Approach	Definition	Application	Pros	Cons
1. Administrative sources	Data, which have been collected by government (national, local), companies and agencies during the pre-implementation phase of project.	- For collecting the most macro-data (e.g., number of residents in a building or settlement), - Detailed sector-specific data (e.g., information on building construction and energy equipment).	- Saving costs for a new data collection process, - Relative quick, reliable and easily available.	- Timeliness verifying, (e.g., change of building occupants), - Useful data could be limited due to data update and protection.
2. Surveying	A method for collecting data through a set of questions from a sample of the population that needs to be studied (IEA 2014, p.29). It can be performed by paperwise or online questionnaires, by telephone or Email. The well-trained interviewers are essential for consistent and unbiased results.	- Energy saving awareness and behaviour of residents, - Household occupancy, - Household structure (e.g., age, gender, education and income).	- More real and target-oriented data, given a well-progressed survey, - Increasing synergy between residents and building owners and energy providers.	- Time consuming because of revisits and back-office work (e.g., information processing and filtering), which could cause potentially high costs in term of money, - Risk of incomplete or fake responses, biases and sample errors, - Requirement of staff training.
3. Measuring	Data are directed measured through the corresponding equipment (i.e. meters) in-	- Collecting consumption data for space heating/cooling, - Electricity consumption	- Accurate and in-time energy consumption at end-use or equipment level,	- High investment of measurement equipment and data transmission network,

	stalled in houses or dwellings. The measured data can either be read by households themselves or transmitted to a processing centre.	for room lighting and other household appliances, - Information on preferred room temperature set in different rooms within a dwelling.	- Intuitive experience of households about their energy consumption, which can shed light on awareness and behaviour change.	- Willingness or acceptance of households to install measuring equipment inside dwelling are crucial, - Possible malfunctioning of equipment.
4. Modelling	A designed model produces a set of output data based on necessary input data and assumptions. All output data need to be validated against existing input data.	- Residential energy consumption varying with occupancy rate， - CO_2 emissions based on inputting emission factors and energy consumption， - Modelling energy consuming behaviour based on occupants needs and awareness.	- Cost- and time-effective， - Designed based on purpose， - Consolidation of a number of data from multiple sources， - Producing many types of data that cannot be measured or surveyed.	- Strongly depends on input data (availability and quality), - Depends on a degree of assumption, which might affect the reasonability and correctness of results.

(IEA 2014, p.28-34)

Depending on the availability of data and the purpose of the indicators, a wide spectrum of indicators is developed to assess energy efficiency in residential sector. In summary, the most common or recommended energy efficiency indicators for residential sector are summarized in Table 4.2.

Table 4.2 Summary list of the main energy efficiency indicators for residential sector

Indicator	**Application/ Coverage**	**Energy data**	**Activity data**
Space heating energy consumption per dwelling	Space heating energy system in building-wise	The total space heating energy consumption of the whole building	Total number of dwellings within the building
Space heating energy consumption per heated area (≈ floor area)	Space heating energy system in dwelling-wise	The total space heating energy consumption of individual dwelling	Heated area (≈ floor area) of dwelling
	Space heating energy system in building-wise	The total space heating energy consumption of the whole building	Heated area (≈ floor area) of the whole building, excluded the common area (e.g., stairways, basement, elevators)
Space heating energy consumption per capita	Space heating energy consumption in household-wise	The total space heating energy consumption of individual dwelling*	Size of household or total number of people who live in a dwelling
Space cooling energy consumption per dwelling with air conditioning (A/C)	Space cooling energy system in building-wise	The total space cooling energy consumption (electricity for A/C) of the whole building	Total number of dwellings with A/C within the building
Space cooling energy consumption per floor area (≈ cooled area)	Space cooling energy system in dwelling-wise	The total space cooling energy consumption of individual dwelling	Cooled area, same as heated area (≈ floor area) of dwelling

	Space cooling energy system in building-wise	The total space cooling energy consumption (electricity for A/C) of the whole building	Cooled area, same as cooled area (≈ floor area) of the whole building, excluded the common area (e.g., stairways, basement, elevators)
Space cooling energy consumption per capita	Space cooling energy consumption in household-/dwelling-wise	The total space cooling energy consumption of individual dwelling*	Size of household, or total number of people who live in a dwelling
Water heating energy consumption per dwelling	Water heating system of building	The total water heating energy consumption of all dwellings	Total number of dwellings within the building
Water heating energy consumption per capita	Water heating system of dwelling	The total water heating energy consumption of individual dwelling	Size of household, or total number of people who live in a dwelling
Water (cold + warm) consumption per dwelling	Water supply system of building	The total water consumption (cold + warm) of all dwellings	Total number of dwellings within the building
Water (cold + warm) consumption per capita	Water supply system of dwelling	The total water consumption (cold + warm) of individual dwelling	Size of household, or total number of people who live in a dwelling
Room lighting energy consumption per dwelling		Total lighting energy consumption	Total number of dwellings within the building
Room lighting energy consumption per floor area	In dwelling-wise	Total lighting energy consumption of individual dwelling	Floor area of individual dwelling
	In building-wise	Total lighting energy consumption of individual building	Total floor area of the whole building, including all common area
Room lighting energy consumption	In household-wise	Total lighting energy consumption	Size of household, or

per capita		of individual household	total number of people who live in a dwelling
Cooking energy consumption per dwelling/household with same energy source	In building-wise	Total cooking energy consumption	Total number of dwellings within a building
Cooking energy consumption per capita	In household-wise	Total cooking energy consumption of a household	Size of household, or total number of people who live in a dwelling
Household appliances energy consumption (electricity) per dwelling	In building-wise	Total appliances energy consumption	Total number of dwellings within a building
Household appliances energy consumption (electricity) per capita	In household-wise	Total appliances energy consumption of a household	Size of household, or total number of people who live in a dwelling
Household appliances energy consumption (electricity) per appliance unit	By the type of appliance	Electricity consumed for any type of appliances	Number of this type appliance

* One dwelling includes one or more households. In term of energy consumption in residential sector, it is more convenient to collect and consider the consumption and activity data for a dwelling as a whole than by household living in the same dwelling.

4.2 Methodology

Two key research components for analysing energy efficiency in residential building are conducted in this PhD research: one is to tap the technical potential of building construction and energy equipment, another is to investigate the impacts of diverse occupant behaviour on residential energy efficiency. The former is supposed to be developed based on Retro-commissioning (RCx) and International Performance Measurement and Verification (IPMVP). The latter is the energy-related occupant behaviour, which is considered as one of six influencing factors of building energy performance, i.e. climate, building construction characteristics (e.g., type, area, orientation, material etc.), building energy service and equipment, operation and maintenance, occupancy rate and occupant behaviour, and indoor environmental conditions and requirement (Yu et al. 2011). The ontology of DNAS mentioned before works as the conceptual framework for analysis of occupant behaviour and occupancy rate. Data collection is performed by the way of surveying elaborated in section 4.1, which provides the factual basis for discussion following the guideline of DNAS.

Based on common RCx and IPMVP, as well as DNAS ontology, an integrated-RCx (IntRCx) concept is proposed to composite the technological factors and human factors that influence residential energy efficiency. This integrated concept aims to introduce an updated standardization, which could serve as a synthesized method or portfolio for energy efficiency analysis of residential building.

4.2.1 Retro-commissioning (RCx)

Retro-commissioning (RCx), also be called Existing Building Commissioning (EBCx) is "*…a systematic process for investigating, analyzing, and optimizing the performance of building systems through the identification and implementation of low/no cost and capital intensive facility improvement measures and ensuring their continued performance.*" (Marlow 2014, p.7). Retro-commissioning is a method to find out and address deficiencies and risks that affect the residential building's energy performance and living comfort. As a systematic method RCx is distinct from the other two concepts: Building Commissioning and Re-commissioning.

- Building commissioning, is a verifying process in new buildings, depending on project scope, some of subsystems (e.g., systems for mechanical, plumbing, electrical, fire/life safety, building envelopes, interior systems, sustainable systems and building security system etc.) that need to be verified to achieve owner's project requirements (OPR) as intended by the building owner and as designed by the building architects and engineers. Building commissioning describes a quality management process that ensures all energy-related systems of building to be designed, installed and operated for an optimal performance. As considered, building commissioning gives a final check of all or some necessary systems, involving to a more progressive process that includes not only systematic verification and testing, but also staff training and thorough documentation of all systems.[115]

- Recommissioning, can be understood simply as a methodical process of testing and adjusting all or some of the aforementioned subsystems in building commissioning. It can take place any time after a building is operated fully. The decision to recommissioning might be triggered by a change in building use or ownership, the onset of operational problems, or some other need. (Haasl and Heinemeier 2006).

[115] http://www.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/files/pdf/publications/commercial/CxRCx_eng.pdf

Retro-commissioning can be understood as another form of recommissioning to some extent, but the building usually has been used longer and have never been commissioned before. RCx relies on building and energy-related equipment documentation, along with functional testing to optimize performance. Four distinct phases generalize the process of RCx briefly: Planning, Investigation, Implementation, and Hand-Off, as Fig. 4.2 illustrated (Haasl and Heinemeier 2006). RCx for enhancing energy efficiency of existing building can take place at any time, unless the facility and/or major equipment are programmed for replacement in the immediate future (DOE 2014).

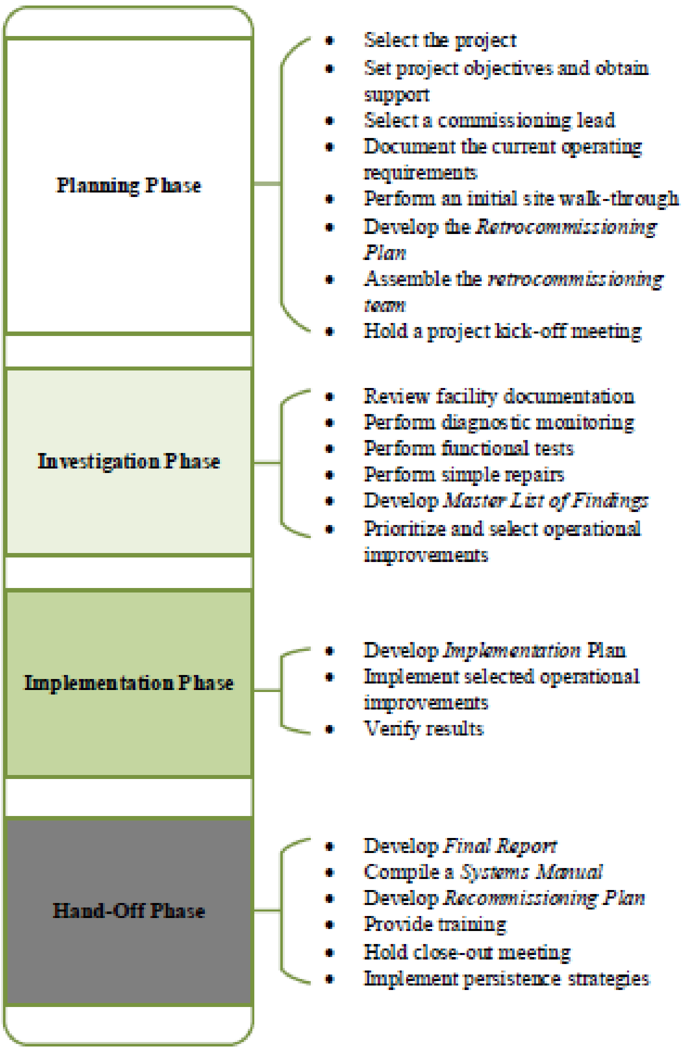
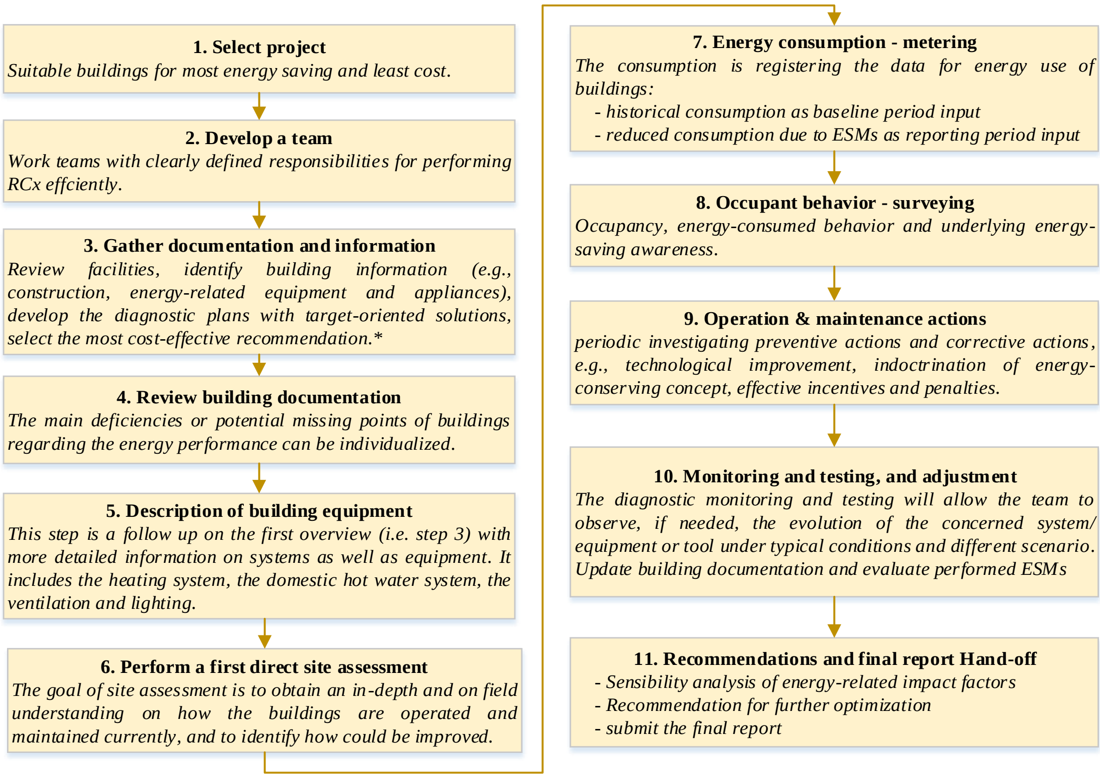


Figure 4.2 Four phases of Retro-commissioning (RCx) processes (Haasl and Heinemeier 2006)

Building is normally designed and constructed reliably and efficiently as far as possible, and expected to be used and operated as efficiently as architects and engineers expected. However, in reality, the building systems may have more or less "wear and tear" and become increasingly unreliable and inefficient owing to incorrect utilization by occupants who cling to their habits and thoughts, as well as lack of regular maintenance by well-trained staffs, or outdated technologies and environmental changes.

Most existing residential buildings in Germany that were built a few decades and before had never undergone a formal and comprehensive commissioning process, even those recently built adhering to some building energy efficiency criteria have not systematical quality assurance services like RCx. Many problems or risks would be analyzed and resolved only after they appeared and caused trouble to daily life of occupants. In particular, social housing occupied normally by people with low income or relative low educational background, which determines that RCx may be more necessary for this building group, if a cost-effective approach is preferred to, because RCx is a results-oriented and comprehensive approach instead of mere „System check-off and restart". The Retro-commissioning process and tools has to be performed within the enclosed timeline. A concrete work process of RCx based on past projects includes the steps described in Fig. 4.3 (Katzenbach et al. 2015).



*"Retrocommissioning Handbook for Facility Managers" 2001.

Figure 4.3 General workflow of RCx considering occupant behaviour

4.2.2 International Performance Measurement and Verification Protocol

International Performance Measurement and Verification Protocol (IPMVP) is used to assess the results of energy saving investments and measures. It is commonly applied in industry or buildings with large-scale systems, thus it is has to be adjusted or simplified when it is applied for residential building category.

IPMVP serves through M&V plan as a guidance document for reporting the implementation of energy saving measures and evaluating the impacts in terms of energy performance and economic performance. The objectives of IPMVP are basically to provide facility owners and managers valuable information about energy system performance in their buildings and allow them to adjust the operation for system optimization (IPMVP 2002). For residential building energy case, a document developed by IPMVP pursues to provide building owner and energy provider a set of details about the performance, deficiencies, energy saving potential and as specification of the approaches used to estimate energy saving, and description of external conditions.

A global equation to determine energy savings after implementing energy conserving measures describes as Equation 4-2 below (IPMVP 2002):

Energy savings =
(energy use in baseline period) – (energy use in reporting period) +/– Adjustments

(4-2)

- Baseline period: pre-retrofit. In this period initial/historical energy consumption and independent variables impacting energy data are collected.

- Reporting period: post-retrofit. Energy consumed in the retrofitted building construction with optimized operational level of energy facilities and changed occupant behaviour, while other external factors (e.g., weather, energy carrier and energy price) are assumed as constants.

Adjustments in this equation are accounted for comparing post-retrofit period and pre-retrofit period more realistically, and it mainly refers to some conditions that influence the energy use in building systems, such as weather, change of heating/cooling area, operational hours of energy equipment, which could affect the building energy performance either positively or negatively. Fig. 4.4 illustrates the common work concept of IPMVP. The application of M&V plan for this PhD research is complying with the thrust of IPMVP. M&V activities include site surveys, metering of energy and independent variables, calculation, and reporting (EIA-FEMP 2015).

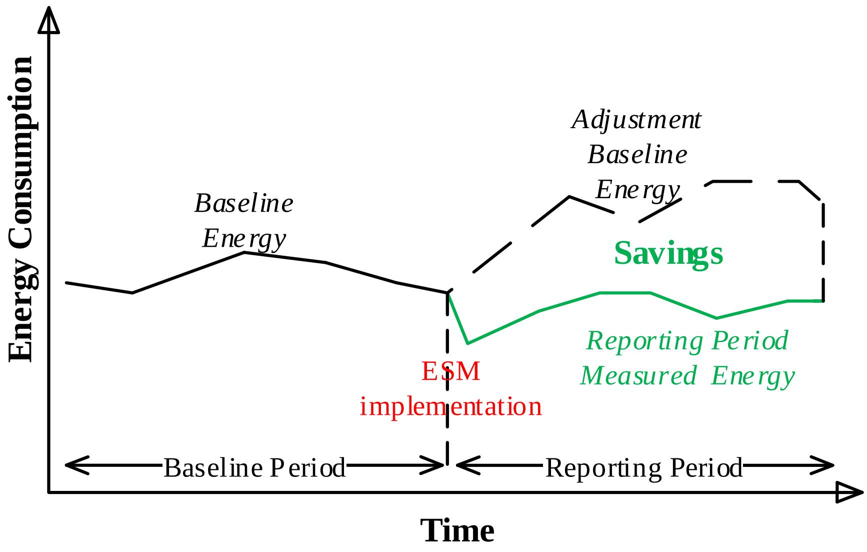


Figure 4.4 Work concept of IPMVP

4.3 Energy saving measures

4.3.1 Selecting criteria

Energy saving measures (ESMs) concern the main tasks of management and maintenance of residential building with the focus on energy efficiency and corresponds to the following criteria:

- Aims of the implemented measures: reduce energy consumption and costs, meanwhile to improve the thermal comfort of building or each dwelling,

- Potential of the implemented measures in the long term:

  - to optimise the economic performance of residential buildings owners (i.e. increasing the market value of buildings and the reputation of real estate company) with cost-benefit-analysis. It concerns direct costs and initial investment costs, as well as annual ongoing maintenance charges (Rosenfeld and Shohet 1999, Rey 2004) and life cycle cost (Wang et al. 2005).

  - to improve the energetic performance of energy providers.

- to improve the social performance of occupants, e.g., awareness and behaviour change, mitigation of household energy poverty[116].
- as well contribute to ecological goals, e.g., reduction potential of CO_2 emissions, life cycle environmental impact (Wang et al. 2005) and water use (Alanne et al. 2007).

- Other criteria, such as optimization of building functionality, comfortability (e.g., thermal comfort, acoustic and visual comfort), as well as security and privacy.

4.3.2 Technical optimisation packages

In accordance with selection criteria of energy saving measures in residential buildings, technical optimisation plays the primary and direct role in reducing energy consumption and costs, and improving the indoor thermal comfort. Technical optimisation measures involve two main assignments: the constructional retrofitting and the efficiency improvement of building energy system. These measures could be implemented based on the status quo of building construction, on the occupants' requirements and the affordable investment (including initial costs, recurring costs, and risk and mitigation factors), in form of individual measure or measures package to meet actual demand. Based on the project experience of building energy efficiency some measure packages could be summarized as follows:

- **Operative management**. Energy system management during the building operation phase refers in this research to optimising the heating curve for rational supply temperature of heating system, regulating DHW supply and installing water submeters, as well as monitoring and reporting. Based on an effective operative management, it aims to achieve an optimized demand response scheme that could shed loads in response to the actual energy demand and the real energy price condition through using a series of dedicated control systems (EU-Project: aFTeR).

  Currently, building management system (BMS) can also follow and control the running time and settings of heating system and help monitor and regulate some of the parameters (the supply temperature, and return/flow temperature of heating system, air flow rates of the ventilation system, etc.). In addition, operative management is strongly influenced by occupant behaviour, therefore energy monitoring instrument for occupants (e.g., web-tools, smart meters) is an interesting so-

[116] Household energy poverty is defined as the level of a household income below the minimum energy costs that are necessary to achieve a satisfactory living condition with a dwelling (Bergasse et al. 2013, Aranda et al. 2017), especially for households living in social housing buildings.

lution to inform and empower occupants and thus contribute to technological optimisation measures.

- **External insulation of building construction**. Heating energy cost is considered as the most part of household energy expenditure, in particular in North- and Central European countries, also in North China. In contrast with electricity consumption largely affected by appliance performance and occupant behaviour, the heating energy efficiency is primarily influenced by the insulation situation of external construction elements, e.g., façades, windows and roofs etc.

  Façades are subject to heavy stress due to the increasing humidity and temperature fluctuations, which lead to not only thermal energy loses also mould and fungi within the indoor area. A study by University Jena, Germany found that the mould infestation of about 60% of 15,000 investigated apartments was due to building materials, which combine with structural components to determine the façade insulation performance. That is to say, the thermal characteristics of building materials (e.g., thermal conductivity λ [W/(m•K)], specific heat capacity c [J/(kg•K)], and thickness of wall or thermal insulation layers etc.). While in 30% of cases, the combination of incorrect ventilation behaviour and building materials was the only cause of mould formation (Weber and Sprungala 2012, p.100).

  In view of rising temperatures, it is advisable to pay attention to a good summer heat protection in the façade thermal insulation layers. This concerns in particular the roof insulation, where the insulation materials must have a good heat storage capacity, thus to delay the heat flow inside the rooms significantly. The insulation of building façade is considered one of the most effective insulation strategies for both new and existing buildings. In particular, for existing buildings, there are two choices to optimizing façade insulation: external or interior insulation solutions. By contrast, external insulation does not take up additional living space and keep the indoor areas being spared from the renovation work, however, interior insulation could save the cost and time for scaffolding but at the expense of reduction of indoor volume.

  Leaky windows (e.g., leaky window frames and one-panel glazing) could cause about 20-25 per cent of the heating energy escapes from heated indoor areas to outside, almost same like uninsulated exterior walls. In order to reduce this thermal loss path, simple measures are sufficient in the first step. For example, replacing the sealing strips of windows, the occupants have the choice between sealing tapes made of foam and rubber profiles in Germany. Foam seals are relatively cheap (about 7-10 Euros/meter), but only hold one heating season. Rubber seals or seals made of similar materials are much more expensive (i.e. cost between 15-25 Euros/meter) with a lifespan of four to eight years. Meanwhile heat escapes through the window glasses if the glasses have a weak insulation character. In

Germany, there are still many windows with single glazing. A quick and relatively simple alternative to optimizing the thermal character is to glue windows with an insulating film, which costs about 10-20 Euros depending on the size of slides. A complete replacement of windows is frequently unavoidable to reduce the energy loss, usually in the case of old buildings that have an extremely poor insulation value. A new standard window for buildings in Germany costs in general about 300 Euro per square meter of window only for material expenses, or 500-600 Euros including installation fees, according to the report from NRW Energy Agency[117]. Window with top quality would be more expensive. The lifespan of windows with state-of-the-art insulation lasts usually 15-20 years.

In addition, it is also useful to optimize the insulation of the roller shutter casings with a high-quality insulation material (e.g., polyurethane or phenolic resin), which is a simple and effective solution. It is important to note that the joints should be after installation of new insulation items well sealed with permanently elastic acrylic sealant.

Roof/attic insulation is suggested implemented from the outside if the attic is inhabited. However, if there is enough space in the attic, an inside roof insulation can be easily realized with an insulation between or under rafters in steep or flat roofs. The cost of roof insulation varies greatly depending on the roof shape, the condition of roof, the selected type of roof insulation and insulation materials.

Basement insulation depends usually on whether it is heated. If the basement is designed as a cold space, the insulation of basement ceiling is recommended, as well the hot water pipes and heating pipes should be well insulated too. If the basement is heated and serves as a useful part of an apartment (e.g., work room or private library etc.), then the basement floor and walls should be well insulated. Similar with other construction components the concrete insulation measures, i.e. from outside or inside, depend on the actual condition, requirements and budget. The external insulation improves the winter and summer indoor living comfort thanks to the reduction of cold wall effect in winter and the reduction of solar gains in summer.

- **Running maintenance**. Comparing with other optimisation solutions, technical maintenance should be a low-investment measure. It includes regular maintenance of heating system with a proper level for achieving an efficient heat distribution inside buildings, complementary insulation of heating system components (e.g., pipe) for reducing thermal loss by transporting process, regular clearance of boiler and hot water tank (e.g., calcium removing) for recovering the efficiency of DHW

[117] http://www.energieagentur.nrw/english/the_energyagency.nrw

supply, installing water filter and water pre-processing system to maintain the facility in a sustainable (e.g., economic and ecological) state.

Although maintenance is relatively cost-effective and time-effective optimisation option, it is at most to reduce the energy waste instead of saving energy or recovering efficiency and thus is recommended as energy saving measure for a short-term instead of long-term strategy.

- **Replacement of systems**. Except for poor tightness building façade, heat losses appear in most existing residential buildings due to old heating systems (e.g., boiler, pump). In traditional boilers, the combustion of energy fuel produces hot gases with potential heating energy that is transferred to the water circulation in the system thanks to the action of the exchanger. During this process, heat losses provoked due to the temperature difference between the hot gases and the air of the combustion and stream contained in the gases, which are blown into the atmosphere and wasted. In contrast, the condensing boiler could take advantage of the potential heat contained in hot gases. This process consists of using the latent heat of the vapour and distributing it into the water of heating system. As a result, the condensing boiler will use and extract waste energy resulting from the combustion process to space heating and preheating the return water before it is heated (EU-Project: aFTeR).

  Comparing with other ESMs, system replacement is a costly and complex measure to improve building energy efficiency. Several factors have to be considered comprehensively, such as the existing heat energy production system, the lifespan of system, and the affordable budget etc.

- **Integration of renewable energy**. The most popular integration of renewable energy into residential buildings includes, for example, solar water heater for DHW supply, PV panels for electricity generation, and geothermal energy as the most reliable renewable energy source (Rezaie et al. 2013) for space heating and cooling, if the average COP value of geothermal system is rough 4. Depending on requirements and budget, these integration approaches could be implemented individually also combined as a hybrid system.

4.3.3 Occupant behaviour analysis

Many studies have proved that energy for operating process represents by far the largest share in the building life cycle (Sartori and Hestnes 2007, p.250). Adalberth published her research report in 1999 and proved that the energy use during the operational period equals 80-85 per cent of the total use during the life cycle with the consumption 5,000-7,500 kWh/m^2 usable floor area given a 50-years lifespan of occupancy (Adalberth 1999).

IPCC has also proved that the greatest part of greenhouse gas emissions in buildings (including commercial and residential buildings) take place during the building operation phase to meet various energy demands (Junnila 2004, Suzuki and Oka 1998, Adalberth et al. 2001). Meanwhile, the process of building operation and maintenance is also the main process, which allows occupants to participate in and play their role through the occupancy rate and their behaviours, thus to negotiate their indoor environment requirements and outdoor environmental conditions. An overview of occupant behaviours by residential energy consuming is conducted as Fig. 4.5 (van Raaij et al. 1983).

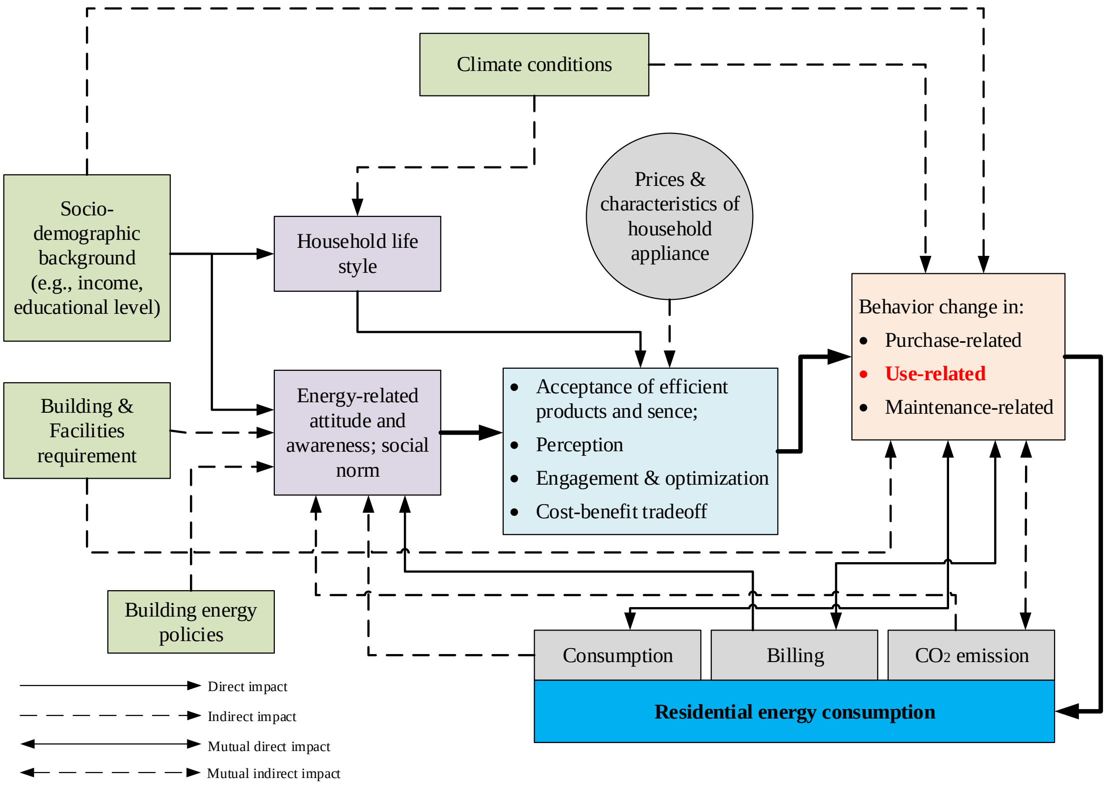


Figure 4.5 Impact factors of occupant behaviour and the interrelation

The residential energy consumption refers to three behavioural phases: purchase, use and maintain:

- The purchase-related decision and behaviour are primarily influenced by the socio-demographic factors. The living tradition determines the household lifestyle to a great degree, however, the household income determines the affordability to purchase energy-efficient products at higher prices. Besides, the educational level influences directly whether the households are willing to purchase those products and use them frequently and correctly.
- The maintenance-related behaviours mean mainly some simple repair or improvement of household energy facilities without or with small additional cost. In a

sense, the occupant awareness about environmental protection and their affordability have impacts on the maintenance activities.

- The use-related behaviour is the key point that refers to the main energy-consuming activities of occupants at home. Occupant behaviours aim to meet the household requirements on heating, cooling, lighting and others, which are affected by factors pertaining to from individual characteristics to social dimension. The energy-related occupant awareness and behaviours can be well interpreted based on Driver-Needs-Actions-System Ontology, as Fig. 4.6 illustrates. **Drivers** represent the internal and external factors (e.g., the location of occupants, and the individual metabolic rate (Turner and Hong 2013, pp.6-7)) that simulate occupants to sprout an energy-related thought or idea, which evoke the **Needs** of occupant to optimize the indoor environmental quality. In the framework of residential building energy consumption, these needs refer to the household requirements on thermal comfort (Fanger 1970, Singh et al. 2014, Yang et al. 2014), visual comfort (Dilaura et al. 2011, Santos 2008), indoor air quality (Szokolay 2008), acoustic comfort (Ginn 1978, Guyer 2009), and privacy (Foster and Oreszczyn 2001), as well as other social satisfaction, e.g., enough view to outdoor environment (Reinhart and Voss 2003). **Actions** are the results of stimulation of those needs and the interaction between occupants and building energy **Systems**, which refer to all energy-related equipment or mechanism inside residential unit and affect the building energy performance through a series of interaction with occupants. The common systems in residential unit include doors and windows, window shutters/Venetian blinds, radiators, lights, water tap, water heater, and plug loads. The impact of the interaction between occupants and systems is affected on the one hand by the occupant actions driven by their living requirements at home, on the other hand by the performance of building energy facilities themselves (e.g., insulation of façade, of window and window frame, COP-value of boilers and water heaters, and air conditioners, etc.). In addition, the occupant attitude and awareness toward energy use would govern how they interact with energy-related building systems.

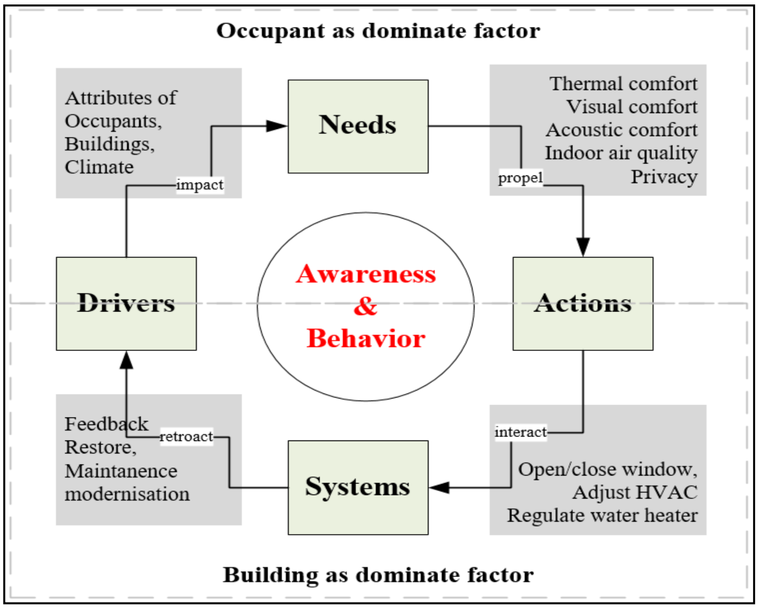


Figure 4.6 Key components of DNAS ontology and the interaction framework

Energy use is invisible to the users, and most occupants have very vague idea about the influence of their daily behaviour on energy consumption (Darby 2006, p.3). Gu has also expressed in his research that energy consumption is the external reflection of human activities. (Gu 2007, p.11). A correct understanding of the human dimensions (e.g., their needs, awareness, abilities and motivations, opportunities and constraints) of energy consumption can catalyse and amplify technology-based energy conservation. This refers to social, cultural and traditional, physiological and psychological factors that shape and impact patterns of human behaviour associated with technology choice, adoption, use and maintenance (IEA 2014, p.21).

With regard to the concrete occupant interaction with building energy system especially, it refers to generally two main aspects: occupancy and energy-related behaviour. Occupancy determines that residents are able or willing to behave or interact with household appliances and energy equipment, so as to meet their requirements on indoor air quality and living comfort. Occupancy plays a very important role in building energy simulation, in particular HVAC utilization, lighting, plug load, natural ventilation or fans utilization, which influence the energy consumption in quantity and the energy balance due to the internal heat gain or loss. It varies among households with different schedules. The variants determining or affecting household occupancy refer mainly to,

- Size of household, i.e. number of family members who reside in the same residential unit.

- Employment status of family members, e.g., full- or part-time employees, retirees, and with/without school-age children, which determine the vacancy of residential units.

Energy-related behaviours are often influenced on the one hand by the availability of the energy-related technological structures at home, and the climate zones where residential units are located, on the other hand by the individual preferred indoor temperature and lifestyle that appear the variation between different types of household structure and social backgrounds. In addition, the accessibility of energy-conservation information and affordability of energy-efficient products have also impacts on occupant consciousness and behaviour. “Energy information knowledgeable” and “Energy-efficient products affordable” for occupants are equally critical to optimizing energy-conservation awareness and behaviour. Gram-Hanssen indicated that residential energy consumption must take into account the impact of information and communication technology (ICT) in the future to a higher degree (Gram-Hanssen 2011, p.998).

It is worthy to note that occupant behaviour is particularly critical for reducing energy consumption in low-energy residential buildings, which have been well equipped with energy-conserving technologies, therefore further energy-saving potential could be explored only with the help of the energy-saving behaviour of occupants. Adjusting the occupant attitudes and behaviours to the surrounding environment (e.g., clothing selection instead of a higher thermal set point or lower cooling set point, rather shower than bath) is crucial for taking full advantage of energy efficiency technologies and thus reducing rebound effect as far as possible. Besides, changing social norms and expectation following from the improvement of technologies (Gram-Hanssen 2011, p.997), as well as building a rational and stable energy prices system should not be overlooked too.

The general approaches for optimise the energy-related behaviours of occupants aim to deliver energy-saving information and consumption feedback to households continually, as well to bridge the effective connection between households and building/energy providers. These approaches refer to, for example, survey, historical data analysis, indoor measuring or monitoring with occupancy sensors or loggers. The process of data collection is conducted not only for the behavioural attributes (indoor area: individual behaviour and schedule) but also for the environmental and social situation (indoor & outdoor area: temperature, relative humidity, CO_2 concentration and luminance). The collected data shall be thorough as far as possible, so as to offset the passive impact of behavioural stochasticity.

Different approaches have their advantages and limits respectively. For instance analysis of historical energy consumption data, which represents the past situation under certain conditions and normally could only as a baseline figure for pre- and post-intervention comparison, when assessing the effectiveness of energy-saving investment, meanwhile relevant economic and political factors shall not be ignored. Measuring or monitoring with information-seeking techniques can detect the occupancy rate and behaviour with a relatively high accuracy, however the issue of privacy has to be considered and solved before installing them. A survey involving questionnaires and interviews is the most common way to inquire such information. In particular, when planning a survey of occupants in residential units, two issues need be clear, i.e. 1) which type of survey is appropriate? 2) and how to motivate occupants to participate in a survey? (Renz 2012).

1) For a pre-post comparison of energy consumption, a longitudinal survey with at least two periods is necessary, which is function with time (*T*, month) as *x*-coordinate and energy consumption (*E*, kWh) as *y*-coordinate, therefore the change of energy consumption before and after implementing energy-saving measures is compared as the (*x,y*) function depicts. If a comparison between different occupants groups who have considerable difference in energy-consuming behaviour and attitudes is the main target, a cross-sectional survey that focuses on one measuring point or period would be appropriate.

2) The response rate of occupants is crucial for the survey results and influences the validity or ultimate value of survey. A high participation or response rate is considerably important for a longitudinal survey process. Except for different survey time or instruments (e.g., questionnaires, face-to-face interview, telephone or online survey), appropriate monetary or non-monetary incentives (voucher, gift) are also suggested for attracting more participants. In addition, frequent information exchange and introduction about household energy saving would contribute to motivate occupants to a certain extent.

Overall, the aim of increasing energy efficiency in residential building and the investigated measures in term of social perspective is to optimize the indoor comfort for residents. Without "comfort" all efforts on residential energy efficiency lost their meaning completely, particular thermal comfort that has defined in ASHRAE Standard 55: thermal comfort is the condition of mind, which expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

4.3.4 Cost-Benefit Analysis

Energy efficiency improvement often needs an initial cost that is an additional investment from the house owners or building contractors. This part of costs could lead to higher upfront cost for housing construction, and thus is likely a barrier to inspire the relevant stakeholders (e.g., building companies or private house owners, public authorities) to invest. However, a rational investment on building energy efficiency can benefit in a long run to reduce energy consumption in quantity, and decline the financial and temporal costs for building operation and maintenance (Laustsen 2008, p.35).

Cost-benefit analysis (CBA) works as a process to facilitate the transfer of the physical estimation into monetary amounts. This quantitative analysis method builds upon directly and fairly the qualitative assessment results. It is structured by all relevant stakeholders who facilitate the business model for a sustainable performance of the implemented energy saving services. Cost-benefit analysis is conducted based on investigating and identifying individual indicators that are related to residential energy efficiency. From the tangible perspective, it refers to,

- Capital and costs for improving energy equipment and building construction.
- Costs for introduction of energy conservation technologies and information.
- Benefits from reduction of energy consumption.
- Benefits from elimination of household CO_2 emission.

And from the intangible perspective, most of benefits are parts of the aims of Retro-commissioning, including,

- Benefits from reducing the engineers‘ visits and maintenance time.
- Benefits from a more comfortable indoor environment.
- Benefits from elimination of household CO_2 emissions.
- Benefits from the rise in the value of building construction for the future market.
- A sound reputation benefited from positive feedback from occupants and a good relationship between building owners and occupants.
- Some negative impacts, such as irritations and inconvenience for occupants during implementing energy-saving measures.

In addition, some economic factors cannot be ignored, e.g., discount rate, net present value, ROI and payback time. CBA for building energy efficiency can be defined as a tool for assessing the viability of energy-related investments for improving building energy efficiency, while taking into account the present and following-up costs and the future benefits for all relevant stakeholders, and evaluating whether these investments make economic sense. A simplified template of CBA model conducted for residential buildings comprises of all energy-related input including the investments or costs, and output, in other words, the benefits. A schema of CBA model for residential buildings with heating energy as domain energy demand is illustrated in Fig. 4.7.

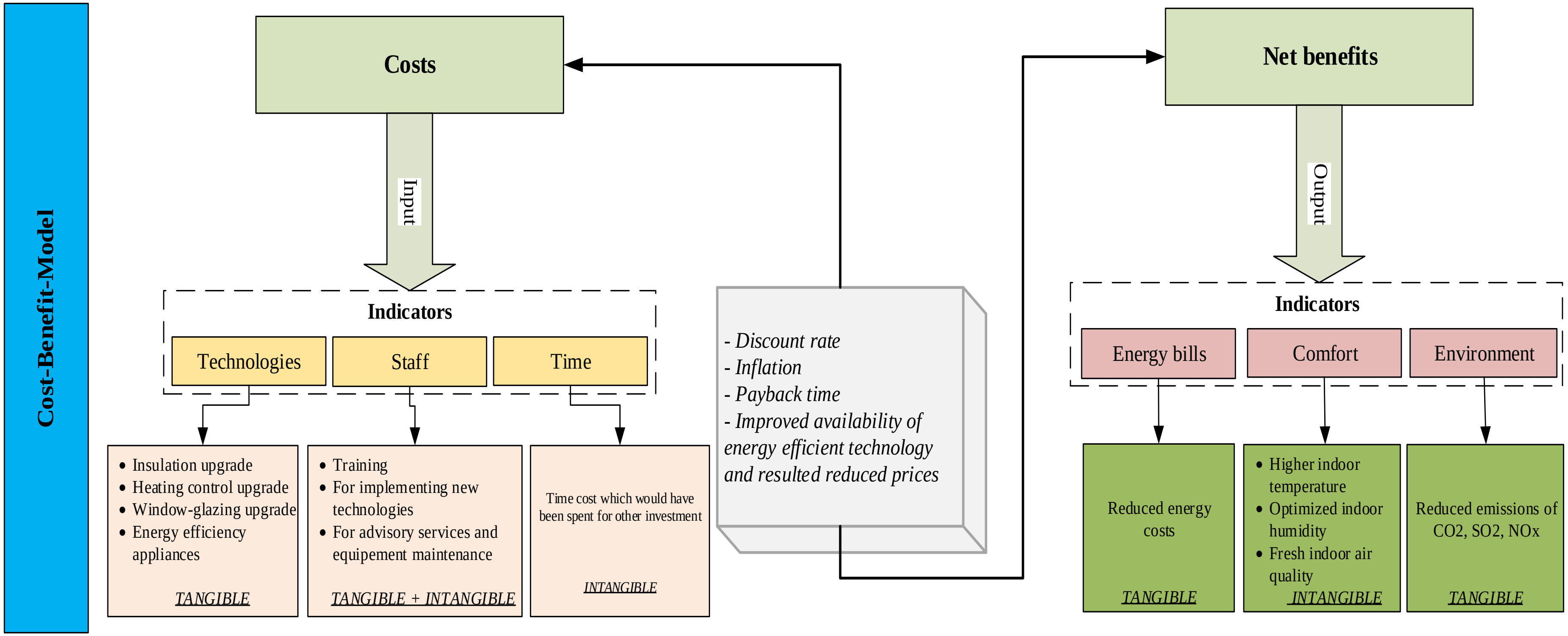


Figure 4.7 Cost-Benefit-Model of energy efficiency in residential building

The conversion of quantitive input into a quantitive and qualitive output through cost-benefit analysis is set up with individual indicators for costs c_i^k and benefits b_j^k. k indicates different categories of the costs and benefits indicator, i.e. k = {*cash, re-deployable, socio, environment*} (BECA-Project Report 2014)[118]:

- k = {*cash}* denotes monetary impacts in tangible form, including the cash flows for technological investment, payments of wages due to additional work and training fee of staff, as well as the saving of energy bills for benefits.

- k = {*re-deployable}* denotes indicators for costs and benefits that are re-deployable factors of production, such as time and other intangible resources, which affect energy saving in quantity indirectly owing to its own values.

- k = {*socio}* represents costs and benefits of intangible social nature of stakeholders, such as the living comfort and satisfaction of households, and work satisfaction of staff.

- k = {*environment}* indicates the environmental benefits from domestic energy efficiency investments.

The calculation of annual costs (AC) is generally considered a one-year time interval, i.e. the value of costs in CBA is the sum of cost c^k of each category k. Similarly, the value of annual benefits (AB) is derived from the sum of individual benefit b^k indicators, in year t, as Equation 4-3 and 4-4,

$$\mathrm{AC}^k = \sum_{i=1}^{n} c_i^k\,(t) \tag{4-3}$$

$$\mathrm{AB}^k = \sum_{j=1}^{m} b_j^k\,(t) \tag{4-4}$$

Within the service life of equipment and services invested by domestic energy-efficiency programs, the costs of technological improvement vary with different discount rate r (%)[119]. Therefore, the present value (PV) of the annual benefit for category k is the discounted annual benefits value calculated by Equation 4-5 and 4-6. The discount rate r influences the minimum ROI and varies depending on the nature of investment projects, operation risks, economic cycles, inflation, and investors‘ attitudes towards risk and so on.

$$PV_{\mathrm{AC}} = \sum_{\boldsymbol{i}}^{\boldsymbol{n}} \boldsymbol{c}_i^k\,(t)/(1+r)^t \tag{4-5}$$

[118] http://www.beca-project.eu/home/

[119] Discount rate (DE.: Abzingungssatz) in Germany

$$PV_{\mathrm{AB}} = \sum_{j}^{n} \boldsymbol{b}_j^{k}(t) / (1+r)^t \tag{4-6}$$

Accordingly, the net present value (NPV), also the cumulative net benefit, is calculated by Equation 4-7 below,

$$\mathrm{NPV}^k = \sum_{t=0}^{T}(\boldsymbol{PV}_{AB} - PV_{AC}) = \sum_{t=0}^{T}[(\mathbf{1}+\boldsymbol{r})^{-t} \cdot (\sum_{j}^{m} \boldsymbol{b}_j^{k}(t) - \sum_{i}^{n} \boldsymbol{c}_i^{k}(t))] \tag{4-7}$$

T means the years when service life comes to the end.

Regarding to four categories of the costs and benefits indicators, the separate NPV value is described respectively as below (Equation 4-8 ~ 4-11), so as to find out the economic NPV (Equation 4-12) and social NPV (Equation 4-13), and therefore to identify the relevant economic ROI and socio-economic return (SER) values, as Equation 4-14 and 4-15.

$$\mathrm{NPV}_{cash} = \sum_{t=0}^{T}[(\mathbf{1}+\boldsymbol{r})^{-t} \cdot (\sum_{j}^{m} \boldsymbol{b}_j^{cash}(t) - \sum_{i}^{n} \boldsymbol{c}_i^{cash}(t))] \tag{4-8}$$

$$\mathrm{NPV}_{redeployable} = \sum_{t=0}^{T}[(\mathbf{1}+\boldsymbol{r})^{-t} \cdot (\sum_{j}^{m} \boldsymbol{b}_j^{redep.}(t) - \sum_{i}^{n} \boldsymbol{c}_i^{redep}(t))] \tag{4-9}$$

$$\mathrm{NPV}_{socio} = \sum_{t=0}^{T}[(\mathbf{1}+\boldsymbol{r})^{-t} \cdot (\sum_{j}^{m} \boldsymbol{b}_j^{socio}(t) - \sum_{i}^{n} \boldsymbol{c}_i^{socio}(t))] \tag{4-10}$$

$$\mathrm{NPV}_{enviroment} = \sum_{t=0}^{T}[(\mathbf{1}+\boldsymbol{r})^{-t} \cdot (\sum_{j}^{m} \boldsymbol{b}_j^{enviro.}(t) - \sum_{i}^{n} \boldsymbol{c}_i^{envio}(t))] \tag{4-11}$$

The economic net benefit value refers to the main tangible costs and benefits, which include generally the financial und re-deployable items, therefore as equation 4-12 depicted,

$$\begin{aligned}\mathrm{NPV}_{economic} &= \mathrm{NPV}_{cash} + \mathrm{NPV}_{redeployable} \\ &= \sum_{t=0}^{T}[(\mathbf{1}+\boldsymbol{r})^{-t} \cdot (\sum_{j}^{m} \boldsymbol{b}_j^{cash}(t) + \sum_{j}^{m} \boldsymbol{b}_j^{redep.}(t) - \sum_{i}^{n} \boldsymbol{c}_i^{cash}(t) - \sum_{i}^{n} \boldsymbol{c}_i^{redep.}(t))]\end{aligned} \tag{4-12}$$

However, the socio-economic NPV takes into account the impacts of social natures, as Equation 4.13 below,

$$\begin{aligned}\mathrm{NPV}_{\text{socio-economic}} &= \mathrm{NPV}_{\text{economic}} + \mathrm{NPV}_{\text{socio}} \\ &= \sum_{t=0}^{T}[(\mathbf{1}+\boldsymbol{r})^{-t} \cdot (\sum_{j}^{m} \boldsymbol{b}_j^{cash}(t) + \sum_{j}^{m} \boldsymbol{b}_j^{redep.}(t) + \sum_{j}^{m} \boldsymbol{b}_j^{socio}(t) - \sum_{i}^{n} \boldsymbol{c}_i^{cash}(t) - \\ &\quad \sum_{i}^{n} \boldsymbol{c}_i^{redep.}(t) - \sum_{i}^{n} \boldsymbol{c}_i^{socio}(t))]\end{aligned} \tag{4-13}$$

The economic ROI measures the amount of return on an investment relative to the investment's cost, for evaluating the efficiency of an investment or comparing the efficiency among different investments. Both economic indicator categories are involved to calculate ROI value, i.e. indictor *cash* and *re-deployable*, and is calculated with equation 4-14 as follows,

$$\mathrm{ROI}_{\mathrm{economic}} = \frac{NPVeconomic}{COSTeconomic} = \frac{\sum_{t=0}^{T}[\left(\sum_{j}^{m} bj,cash(t) + \sum_{j}^{m} bj,redep.(t) - \sum_{i}^{n} ci,cash\,(t) - \sum_{i}^{n} ci,redep.(t)\right)/(1+r)t\,]}{\sum_{t=0}^{T}[(\sum_{i}^{n} ci,cash\,(t) + \sum_{i}^{n} ci,redep.(t))/(1+r)t]} \quad (4\text{-}14)$$

The socio-economic return (SER) of energy efficiency investment defines the ratio of $\mathrm{NPV}_{socio\text{-}economic}$ and the cumulative costs involving economic cash flow and cumulative investments on social and environmental issues, it is calculated with equation 4-15 as below,

$$\mathrm{SER} = \frac{\sum_{t=0}^{T}[(\sum_{j}^{m} \mathrm{bj,cash(t)} + \sum_{j}^{m} \mathrm{bj,redep.(t)} + \sum_{j}^{m} \mathrm{bj,socio(t)} + \sum_{j}^{m} \mathrm{bj,envir.(t)} - \sum_{i}^{n} \mathrm{ci,cash\,(t)} - \sum_{i}^{n} \mathrm{ci,redep.(t)} - \sum_{i}^{n} \mathrm{ci,socio(t)} - \sum_{i}^{n} \mathrm{ci,envir.(t)})/(1+r)t]}{\sum_{t=0}^{T}[(\,(\sum_{i}^{n} \mathrm{ci,cash\,(t)} + \sum_{i}^{n} \mathrm{ci,redep.(t)} + \sum_{i}^{n} \mathrm{ci,cash\,(t)} + \sum_{i}^{n} \mathrm{ci,cash\,(t)})/(1+r)t]} \quad (4\text{-}15)$$

SER is a significant assessment criterion of the effectiveness and viability of building energy efficiency investment, in particular for the residential buildings occupied by diverse household groups that have different social backgrounds. The involved environmental indicator relates to on the one hand individual indoor air quality that is an intangible factor reflected by optimization of living comfort, on the other hand could be a tangible index by calculating the CO_2 emissions that are supposed to be eliminated through improvement of energy efficiency and reduction of fossil energy or increase of renewable energy.

Cost-benefit analysis reflects the economic feasibility of an investment. However, it could also find out the affordability of the investment for different target populations, if taking the social nature of occupants into account. Based on a holistic CBA, national and local governments are able to make a rational investment decision and bring the function to relieve the problem of affordability in low-income group, and bridge the gap between the benefits for society and the constraints for poor households (Winkler et al. 2000).

4.4 Simulation based approaches

Building Information Modelling (BIM) solutions with energy analysis make design practices more sustainably for architects and engineers to simulate, analyse and visualise building energy performance. With a set of energy analysis in building simulation programs designers are capable to adjust their designs from the conceptual phase to the detailed specification of building systems and the involved energy configuration.

There is an increasing range of dynamic building energy simulation tools (BESTs) available for research and project application. based on the mathematical models and the entered variables, these tools provide the ability to calculate, analyse and illustrate the increasingly complex energy requirements with graphical user interface (GUI), to develop and demonstrate compliances of building energy codes, and implement building energy rating programs (Zhu et al. 2013). Fig. 4.8 illustrates the general building energy simulation process.

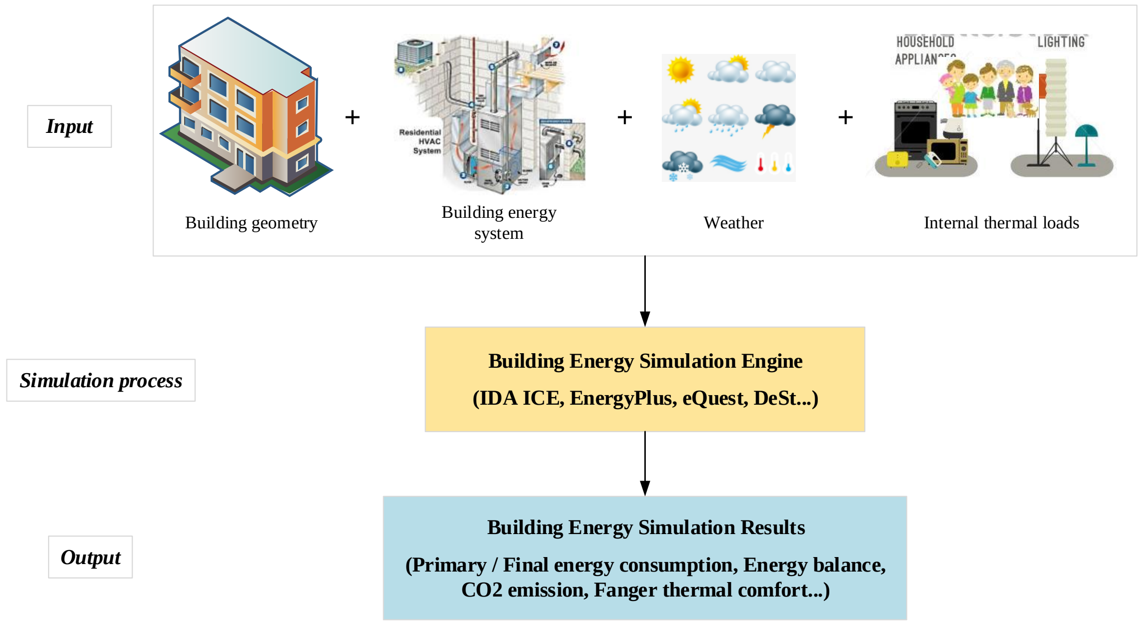


Figure 4.8 General building energy simulation process

4.4.1 Operation steps of building energy simulation tools

In general, all building energy simulation software tools work through three steps to perform the energy simulation of buildings (Sousa 2012) for the required modelling results, such as CO_2 emissions, energy costs, satisfaction ratings of building occupants (e.g., PMV[120] and PPD[121] values according to DIN EN ISO 7730 and DIN EN 15251).

1) Creating building models. As the first step of building energy simulation process, the creation of building models is achieved through generally two ways, i.e. directly inserting the coordinates in the simulation software or uploading the building model files from other software like AutoCAD or Sketch Up, based on the

[120] PMV: Predicted Mean Vote, -3 ~ 3, i.e. cold (-3), cool (-2), slightly cool (-1), neutral (0), slightly warm (+1), warm (+2), hot (+3)

[121] PPD: Predicted Percentage of dissatisfied

compatibility of software. The characteristics of building construction are specified during the model developing process, e.g., geometry, orientation and materials, which are the components of building architecture and represent the building models for the second step, i.e. building energy simulation.

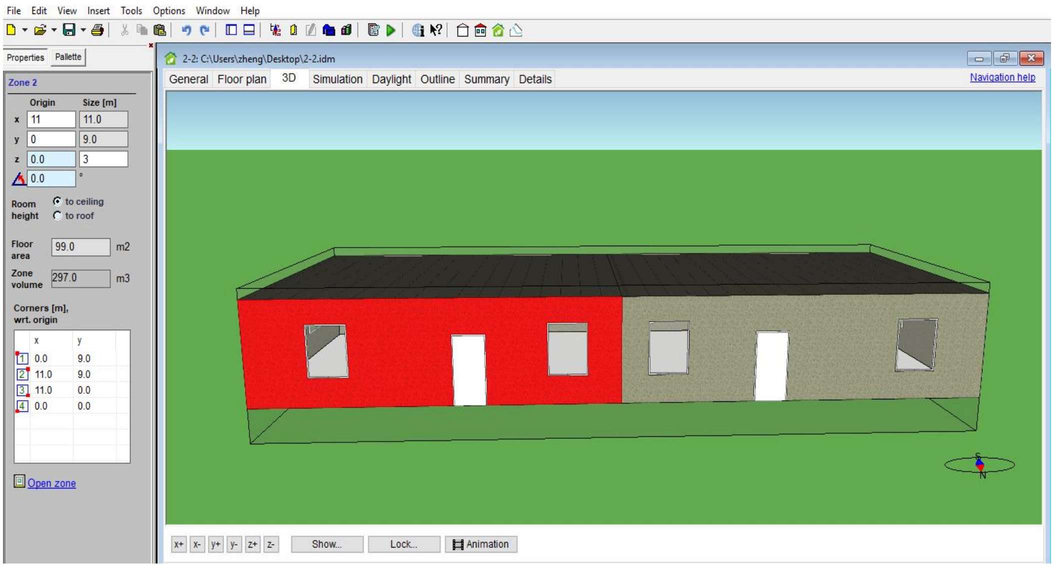


Figure 4.9 Building model creation by inserting the coordinates with simulation tool “IDA ICE“.

2) Building energy simulation. This step is a calculating process based on the variables entered from the first step. This is a time-consuming process depending on the amount of input and the range of required simulation results. With regard to residential buildings, it is important to specify the building structure referring to thermal performance, the energy-related occupant activities, the available household appliances (furnaces, refrigerators, lighting, air conditioner etc.) and their COP values, as well as their daily schedules. In addition, other energy-related information is allowed to enter, such as CO_2 emission per unit energy consumption, energy prices, and the weather conditions etc. During this simulating process, the errors or warnings might be caught, therefore which need to be corrected iteratively so as to continue the simulation. For example, simulation process of software IDA ICE, as Fig. 4.10-4.12 depict.

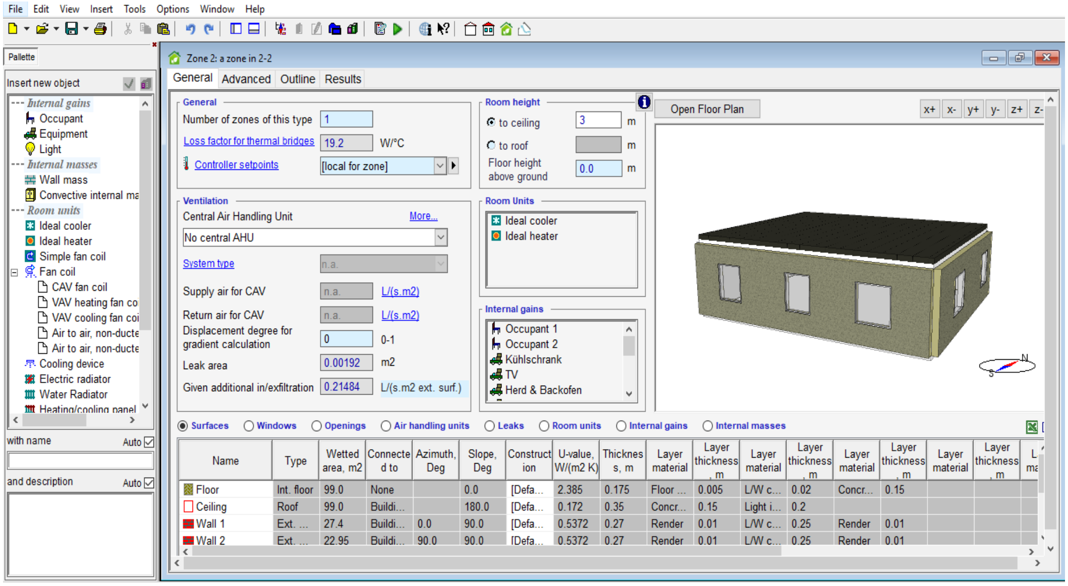


Figure 4.10 View of the interface of parameter input in IDA ICE

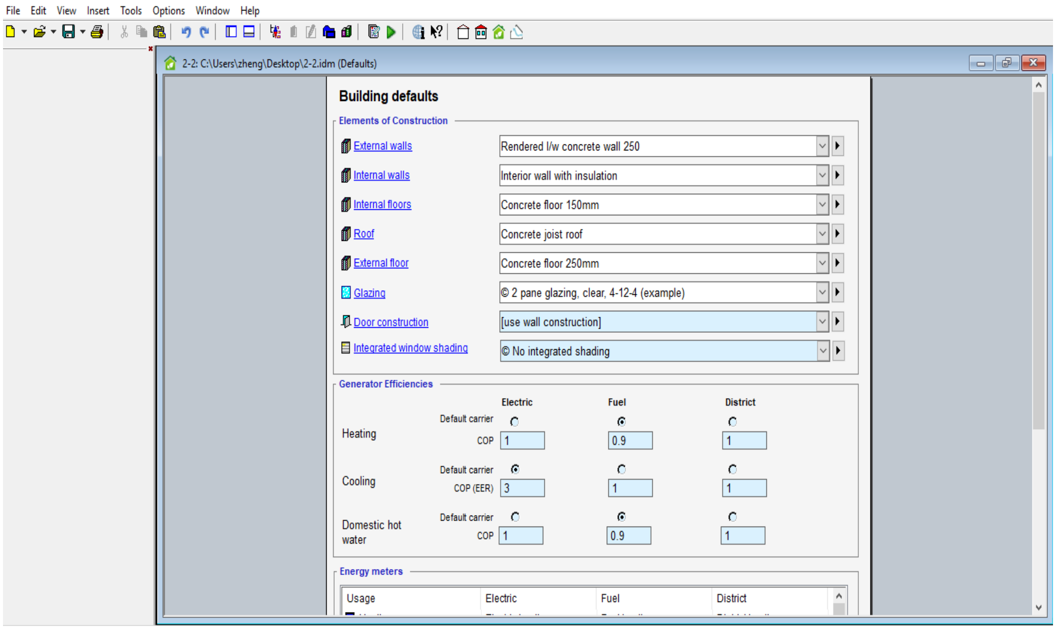


Figure 4.11 Introduction of building materials in IDA ICE

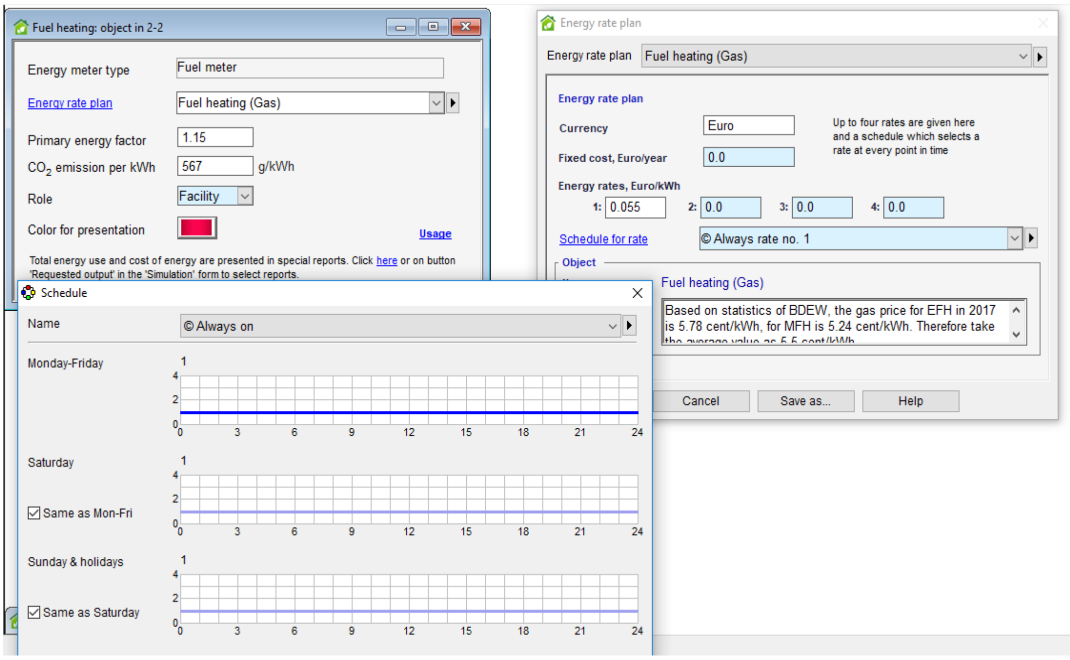


Figure 4.12 Introduction of energy-using schedules in IDA ICE

3) Analysis of simulation results. Depending on the features of building simulation software and the required simulation results pre-set in step 2, the analysis reports are presented in form of diagram, table, image or description, for example, the modelling results of IDA ICE, as Fig. 4.13-14 depict.

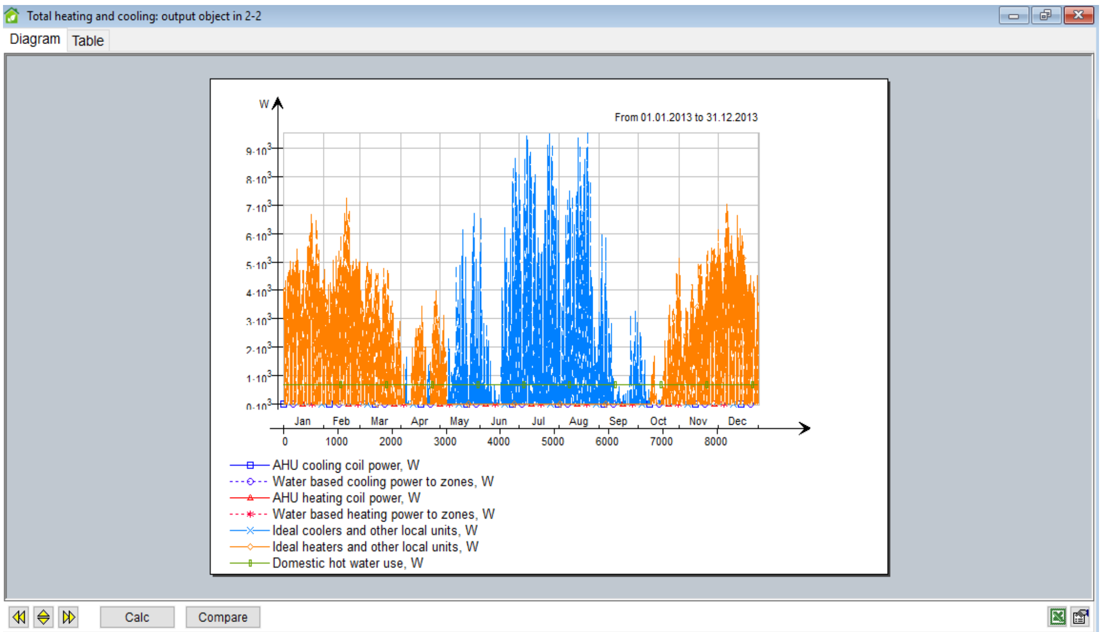


Figure 4.13 Energy consumption results simulated by IDA ICE

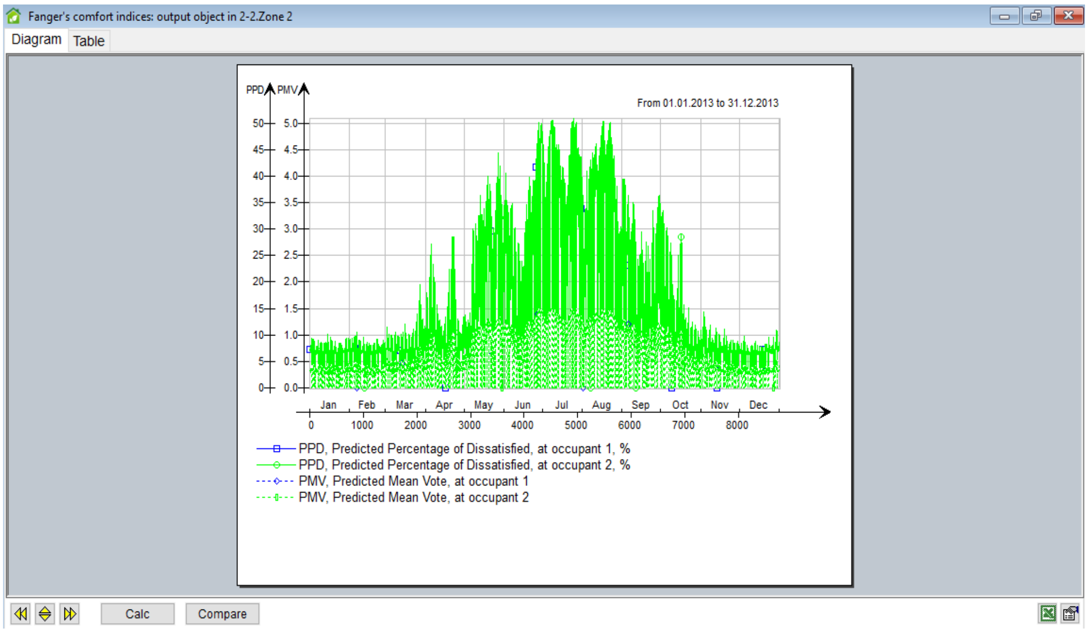


Figure 4.14 Energy-related social characteristics of occupants (e.g., PMV, PDD) simulated by IDA ICE

4.4.2 Overview of building energy modelling software

Building energy modelling software is developed for simulating energy performance, i.e. providing targeted and localized prediction building energy consumption, indoor air quality and building energy balance, such as indoor temperature and relative humidity, indoor CO_2 concentration, and natural illumination demand etc. In addition, increasing simulation software allows to improving building energy performance through integrating passive energy systems, such as solar energy or geothermal energy, and passive constructive components with specific ventilation and shading systems (Sousa 2012). An overview of the most used building modelling software is introduced in Table 4.3 (Crawley et al. 2005, Rallapalli 2010, Sousa 2012, Zerroug and Dzelzitis 2015).

Table 4.3 Comparison of features of building energy simulation software[122]

	Energy-Plus	eQuest	IDA ICE	ESP-r	TRN-SYS	Design-Builder	DeST
Geometric description							
Building envelope (walls, roofs, windows)	x	x	x	x	x		x

[122] https://www.buildingenergysoftwaretools.com/

Building materials and façade coating	x	x	x	x	x		x
Polygons and multi-storeys construction	x	x	x	x		x	x
Import of building body or zone geometry from CAD programs	x	x	x	x	x	x	
Export geometry to programs	x	x	x	x		x	
Site shading and orientation		x	x				x
Calculation of thermal bridges	x	x	x	x	x		
Extra energy gains or loss			x				x
Solar radiation level configuration	x		x		x		x
Air tightness configuration	x	x	x	x			x
Daylighting and illumination control	x	x	x	x		x	x
Ground properties (ground temperature and insulation)			x				x
Indoor air CO_2 level setting and calculation	x		x		x		x
HVAC systems							
Efficiency of energy generators	x	x	x	x	x		x
Air handling unit configuration	x		x	x	x		x
Distribution systems configuration	x	x	x	x	x		x
Electrical equipment and appliances							
COP of electrical appliances			x				x
Primary energy factor			x				

Renewable energy systems							
Solar energy	x		x	x	x		
Photovoltaic panels	x			x	x		
Hydrogen energy				x	x		
Wind energy				x	x		
Simulation processes and solutions							
Simulation of loads and consumption	x	x	x	x	x	x	x
Energy balance	x	x	x	x	x		x
Indoor air quality (air age, CO_2 in *ppm*, relative humidity in %)			x			x	x
Calculation of Fanger's comfort indices			x			x	
Iterative solution of nonlinear systems	x	x	x	x	x		x
Variable time intervals per zone for interaction of HVAC system	x			x			
Integration of human factors							
Occupancy rate (schedule)		x	x				x
Window control for natural ventilation	x		x	x	x		x
Thermostat settings		x	x				x
Localization							
Building energy codes and standards			x				
Climate (temperature, wind profile)		x	x			x	x
Public holidays			x				
Economic evaluation							

Simple energy and demand charges	x	x	x	x	x		x
Scheduled variation in all rate components	x	x	x		x		x
User selectable billing dates	x	x					
User friendly interface							
Graphic data input	x[1]	x	x			x	x
Graphic results output		x	x			x	x
Input data[2]	ifc, gbXML, text	gbXML, .dwg, .dxf	.ifc, .dxf, .dwf, .cmx, .dgn	XML	.skp, ASCII, .xml	gbXML, .dxf, .pdf, .bmp, .jgp	.dwg
Output data	ASCII	.dxf, gbXML, .xls	.html, .doc, .xls, .jpeg, .jpg, .png, .tiff, .bmp	XML, csv, VRML	ASCII (HTML , C++)	3-D dxf, .epw, .csv, .tmy, .tmy2	.txt, .xls, SQlite

1. Through third party software
2. Bahar et al. 2013

4.5 Conclusion

Residential building energy efficiency can vary dramatically between households. A comprehensive investment with necessary hypothesis is inevitable for determining optimisation measures and choosing the available simulation tools. Integrated Retro-commissioning concept is an technique developed through integrating occupant behaviour analysis concept into the common retro-commissioning process, which means, combining the subjective optimization by occupants with objective retrofit and modernization by energy and technics providers, aiming to provide a holistic building energy analytical portfolio. Occupants evaluate all the optimisation measures so positive that they prepare to accept and adequately use them in the long term, however, which depends upon not only the supply of energy-saving household appliances and energy-efficient building technologies, also on a greatly improved awareness of energy conservation of occupants based on the comprehensive analysis of behaviour. It pursues to analyse the synergetic effect of occupants' interaction with residential energy efficiency measures, to achieve qualitative assessment results effectively and fairly. With this analysis method three energy user types could be identified, i.e. energy frugal, energy neutral and energy agile user, which helps solve problems with targeted measures that benefit relevant aspects, i.e. energy-related and non-energy related, by improving residential energy performance, as briefly summarized in Fig. 4.15.

Simulation-based optimization approaches are undoubtedly the promising ESMs to achieve sustainable targets for building energy conservation. Building energy simulation tools have a complex multi-disciplinary technique and different characteristics that involve an amount of relevant information (e.g., engineering, climate and environment, economics, ergonomics, mathematics etc.), aiming to provide a specific scope of application.

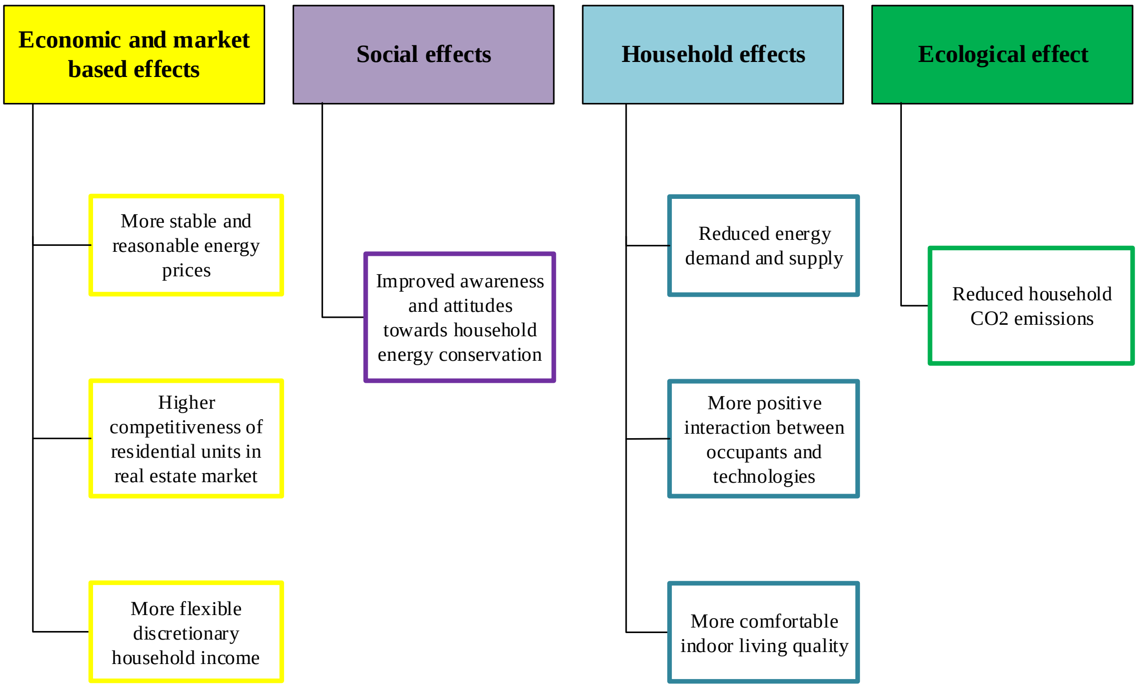


Figure 4.15 Benefits of improving residential energy efficiency

5 Case study

One social housing building in Darmstadt (Hessen, Germany) was chosen for exploiting residential building energy efficiency with regard to the occupant behaviour characteristics, the performance of energy system and the energy-related attributes of building construction. The analysing results of investigated cases should mainly prove the impacts of the diversity of occupants behaviour and the performed energy saving measures on energy consumption reduction and optimization of indoor environmental quality. Therefore, the accuracy and completeness of collecting data were critical, and the identical characteristics of dwellings and occupants within the whole measuring periods should be assured. It was particularly noteworthy that the dwellings with a change of occupancy (e.g., relocation of households) during the measuring and analysing processes must be excluded. Due to data protection, some of the data had to be assumed within the parameters of simulation software as similar to real status as possible. However, other information necessary for simulation related to residential building energy consumption was taken primarily based on field survey and measuring.

Firstly, the approaches of data collection and processing were introduced based on the project experiences, which reflected the real situation and challenges we were facing. A simulation process would demonstrate the concrete diversity of occupant interaction and their impact on energy consumption and indoor environmental quality and the satisfaction of occupants, which provides an opportunity and perspective for further research and practical operation.

5.1 Data processing

In general, the data processing consisted of two parts: data collection and data screening. Chapter 5.1.1-5.1.5 introduced the collecting methods and collecting content about various energy-related data respectively, which comprised residential energy consumption, information on energy-related occupant behaviour, and technical attributes of building environment and energy system, as well as climate information. Some unforeseen circumstances appeared during the 3-years project period, such as change of tenants or data missing, therefore data filtering was required to ensure a rational and reliable data analysis.

The data collected before and during the project could be generally distinguished as internal and external information. The former, i.e. internal information, varied during the whole process and interact with each other, while the latter, i.e. external information, referred to mainly the variables that were normally identified before implementing the project and could not be changed by human involvement. Figure 5.1 depicted the scope of collected data and the approaches for data collection in this research work.

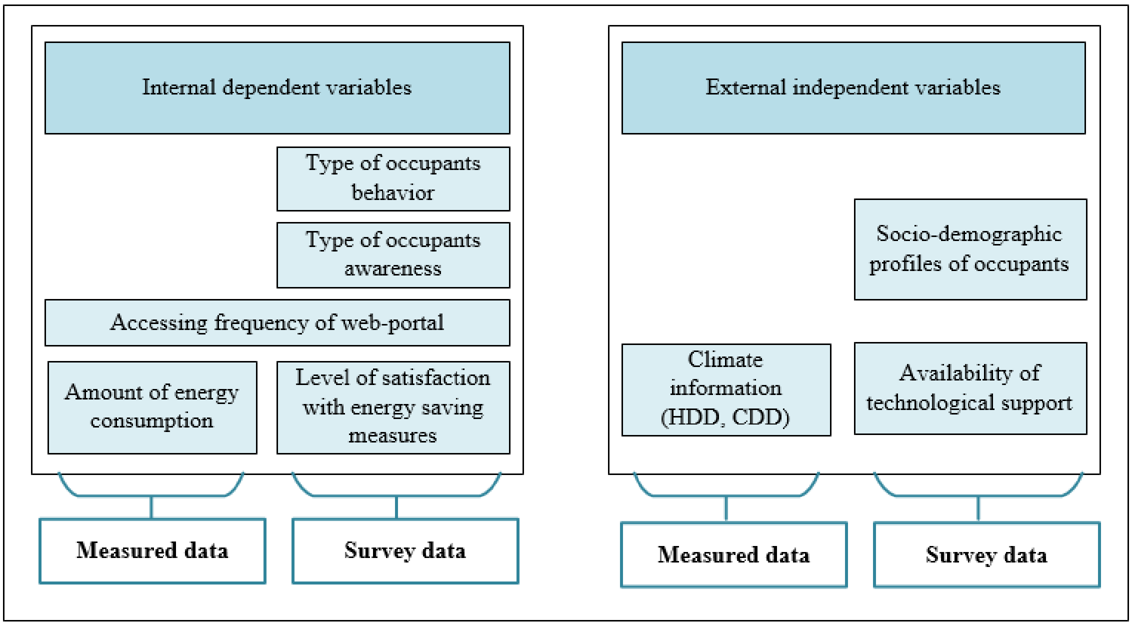


Figure 5.1 Approaches for data collection

Social housing building located in Händelstraße 91 Darmstadt (Wixhausen) about 15 km north from downtown Darmstadt, as Fig. 5.2 shown, is implemented ESMs with the focuses on occupant behviour and thermal energy system that were modelled for analysing the impact of both subjective and objective factors on household energy consumption.

Figure 5.2 Social housing buildings for case study - Händelstraße 91, Darmstadt (Wixhausen), 12 dwellings in four floors.

Data for analysing building energy efficiency was generally divided into two categories: deterministic and stochastic parameters. The former referred mainly to the energy-related parameters of building design, i.e. the general characteristics of building construction and energy equipment that were identical for all investigated dwelling units and identified as independent external influence factors. Besides, the geographic and climate conditions were also deterministic factors for building energy analysis. Stochastic parameters in simulation models referred to mainly occupancy and schedules of using energy equipment for heating and cooling, and household appliances, and the individual preference of heating set-point, as well as the changing internal heat gains over occupied periods. Since those values differentiated in each dwelling owing to occupancy and behaviour, which could be identified as dependent internal influence factors. Table 5.1 showed the data categories for building energy efficiency within the scope of technical level. The concrete data about case study was introduced in the following sections.

Table 5.1 Energy-related building design parameters

Energy modelling input parameters	**Deterministic parameters**	**Stochastic parameters**
Building general	• Building location/address • Year of construction • Building/dwelling areas for thermal simulation • Envelope materials - U-value - Thermal bridges - Air tightness - Absorption coefficient - Solar transmittance - Solar heat gain coefficient - Visible transmittance	N/A
Energy system	• Year of installed facilities for energy, heating and water supplying • Modern thermostatic valves • Ventilation system	• Internal gain • Heating set-point • Occupancy schedule • Lighting schedule • Household appliances schedule
Geographic and climate conditions	• Latitude, longitude and elevation • Average annual temperature • Heating degree days (HDD) or cooling degree days (CDD)	N/A

5.1.1 Weather data

The social housing building is located in the climate zone where the climate is considered to be Cfb according to the classification by Köppen-Geiger[123] (or climate type 5C according to ASHRAE Standards 90.1-2004 and 90.2-2004 Climate Zone), i.e. the climate characteristics of Darmstadt is described as temperate without dry season and with warm summer[124,125] (Beck et al.). The average annual temperature in Darmstadt was high similar like Frankfurt am Main, i.e. 11.4 (+0.9) °C in 2011 and 10.9 (+0.4) °C in 2012[126]. The details of climate and wind information of case building in Darmstadt are illustrated in Appendix 7 and 8, which are based on climate data of Darmstadt in 2012 from Deutscher-Wetterdienst (DWD) and the geographic location data (Darmstadt, Germany: Latitude = 49.87 N°, Longitude = 8.65 E°, Elevation = 144 m, Time zone = 1.0 E h)[127] and generated by simulation tool IDA ICE 4.7.1. Based on geographic location and historical climate conditions the heating limit temperature for HDD was chosen 15°C which is the temperature below which buildings need to be heated. Instead of number of days, HDD is the number of degrees that a day's average temperature is below the regulated heating limit temperature. The German Meteorological Office[128] and the Institute of Habitation and Environment (IWU)[129] provided the heating degree days of 2011 and 2012 in Darmstadt, as Table 5.2 listed below. The concrete calculation is described in Appendix 7.

Table 5.2 Heating Degree Days of Year 2011 and 2012 in Darmstadt Germany

	2011	**2012**
January	422	385
February	371	493
March	256	210
April	67	179
May	38	41
June	9	11
July	10	0
August	4	0
September	12	41
October	171	188
November	326	288
December	332	385

[123] http://koeppen-geiger.vu-wien.ac.at/

[124] https://en.wikipedia.org/wiki/K%C3%B6ppen_climate_classification

[125] https://www.weatherbase.com/weather/

[126] http://www.wetterkontor.de/de/wetter/deutschland/monatswerte-station.asp

[127] Google and ASHRAE 2013

[128] Deutscher Wetterdienst, DWD. https://www.dwd.de/DE/Home/home_node.html

[129] „Gradtagszahlen Deutschland“ by German Institute of Housing and Environment, Institut Wohnen und Umwelt, IWU.

Total	**2017**	**2219**

(Source: IWU and DWD)

5.1.2 Building design parameters

According to Building Typology developed by IWU and Hessische Energiespar-Aktion[130], social housing building in this case study was classified as type MFH_E, as Appendix 9 introduced. It is a typical four-storey residential building with gable roof. As a simple building construction in this period (i.e. 1958-1968), concrete as main building material for floor and balconies, plastered masonry walls of hollow blocks. Besides, requirements for thermal insulation according to DIN 4108 are mostly met. Central heating system in the basement (coke, gas, oil) or gas floor heating system or gas ovens are used instead of solid furnaces (Loga et al. 2015).

In this building 12 dwellings in four floors are divided into three different living areas, i.e. each floor has three different types of dwelling units: in 60.17 m^2, 28.62 m^2 and 82.31 m^2 respectively.

The energy facilities in this building refer to dwelling-wise equipped radio frequency heat cost allocators (which is obligatory in Germany and regulated by the German Heat Cost Allocation Ordinance[131]) and modern thermostatic valves, water sub-meter and remote reading infrastructure. Gas boiler is the unique heat energy source and each dwelling is heated through individual radiators in heating season. Heating and hot water generation are achieved through central boilers that are installed in the building basement. In addition, the weighted average historical energy consumption data in 2010 was offered by energy provider, which served as benchmarking for further comparison after implementing energy-saving measures, i.e. the annual consumption of heating, cold water and hot water accounted for (BECA: D1.1):

- Heat: 202.0 kWh/m^2/a for room heating and domestic hot water supply
- Cold water: 58.34 m^3/per./a
- Hot water: 22.88 m^3/per./a

Before implementing ESMs there was no heating and energy management yet. Typical technical defects were reported by occupants due to the occasional malfunction of energy equipment, and the exhaust emissions were measured once a year from the chimney

[130] http://www.energiesparaktion.de; https://www.impulsprogramm.de

[131] Heizkostenverordnung (HKVO): the German Heat Cost Allocation Ordinance. http://www.heizkostenverordnung.de/

sweep. The heating bill was provided to occupants only once a year by building provider, i.e. occupants had not any other option to acknowledge their energy consumption data for heating (in kWh) and DHW (in m^3) during the year. It caused some complaint of occupants in relation to energy consumption and billings, such as much higher energy costs than expected, the wrong billings because of heat cost allocators and water meters. These problems revealed that it was urgent to improve the accuracy, comprehensibility and frequency of information on individual energy consumption, and meanwhile to enable high real-time operation monitoring and controlling by energy provider and high frequent access to energy data checking by occupants. The basic energy-related data for modelling was illustrated in Table 5.3.

Table 5.3 Data input for building energy simulation - case building Haendelstr. 91, Darmstadt

Energy-related information of case building – Before ESMs implementation		
	Address:	Haendel Str. 91, Darmstadt
	Building type:	Multi-family House (MFH), Low-rise apartment
	Building age classification:	5 [E] 1958-1968
	General characters of building in this period: Typical 3- to 5-storey, with gable or flat roof, partly heated attic, plastered masonry walls with hollow blocks, air bricks, woodchip-concrete blocks or similar plastered, reinforced concrete ceilings, strong thermal bridges on cantilevered balconies.	
	Number of floors:	4
	Number of dwellings (zones)	12
	Heated living area:	684.36 m^2
	Unheated area (corridors):	52.2 m^2

Geometry of building dwellings (Heated area)						
Dwelling/zone	Length (m)	Width (m)	Area (m^2)	Floor to ceiling (m)	Volume (m^3)	Floor Nr.
Zone 1	9.15	9.0	82.35	2.6	214.11	The ground floor
Zone 2	10.2	5.9	60.18	2.6	156.47	The ground floor
Zone 3	10.2	2.8	28.56	2.6	74.26	The ground floor
Zone 4	9.15	9.0	82.35	2.6	214.11	The 1st floor
Zone 5	10.2	5.9	60.18	2,6	156.47	The 1st floor

Zone 6	10.2	2.8	28.56	2.6	74.26	The 1st floor
Zone 7	9.15	9.0	82.35	2.6	214.11	The 2nd floor
Zone 8	10.2	5.9	60.18	2.6	156.47	The 2nd floor
Zone 9	10.2	2.8	28.56	2.6	74.26	The 2nd floor
Zone 10	9.15	9.0	82.35	2.6	214.11	The 3rd floor
Zone 11	10.2	5.9	60.18	2.6	156.47	The 3rd floor
Zone 12	10.2	2.8	28.56	2.6	74.26	The 3rd floor

Building azimuth (north-based):	20°, north-northeast
Window location:	West-east

Architecture (characters of building construction)*		
Construction	Material (before ESMs)	U_0-value W/(m²·K)
External walls	Masonry of hollow blocks, hollow bricks or grid tiles	1.2
Roof/top floor ceiling	Concrete ceiling with 5 cm insulation	0.6
Floor	Concrete ceiling with 1 cm insulation, cement screed	1,6
Window	Double glazing in plastic frame	3.0
Integrated window shading	N/A	-

Building energy equipment**		
Heat supply system	Description	Energy demand for 1 kWh heat supply
Heat system	Gas central heating system, which is low-efficient, i.e. low-temperature boiler, high heat losses of the distribution pipes	1.21 kWh (Gas)
Domestic hot water system	Combination with heat generator (low temperature boiler), poorly insulated circulation pipes	3.82 kWh (Gas)
Total heat supply system	Primary energy consumption, non-renewable energy sources, electricity for auxiliary energy	1.68 kWh (Primary energy)

* architectural data base on German Building Typology (Loga et al. 2015).

**data of building energy equipment bases on German Building Typology (Loga et al. 2015).

5.1.3 Investigated building energy saving measures

Except for necessary optimization of building insulation in façade, ceiling and basement, the main ESMs for this case study mainly focused on improving the performance of energy system and energy-related behaviour and awareness of occupants. Two energy-saving services were designed to for the investigated building. One was energy management service (EMS), another was energy use awareness service (EUAS). EMS enabled housing managers to optimize building energy management by monitoring the energy consumption and performances of energy equipment precisely, which include:

- **Real-time monitoring and management**, which provided building manager the heating energy consumption data. The outside and inside temperature with measurements frequency was every 15 minutes. Therefore, the building manager could spot failures and malfunctions in time to avoid more energy waste,

- **Balancing energy production based on real demand**. It was possible to synchronize the radiators in the dwellings with the heater located in the basement of the building, therefore to produce the amount of energy that was really needed by all dwellings in a building,

- **Integration renewable energy**, which provides an alternative to integrate renewable energy (e.g., biomass, solar panel) in the energy mix of residential buildings, if the conditions of located weather and energy provision allow.

Fig. 5.3 sketches the work concept of the energy consumption data collecting and exchanging devices provided by Techem GmbH[132] (BECA: D1.2, pp. 37-39).

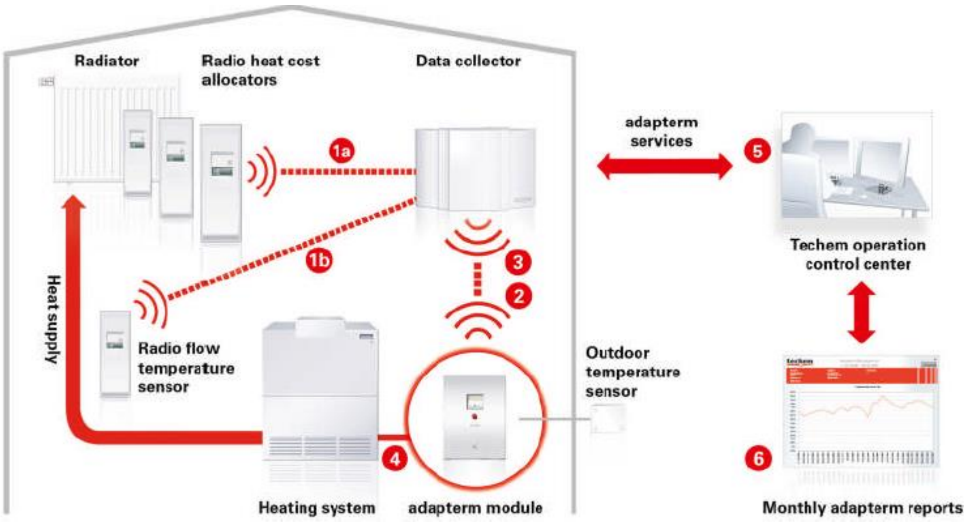


Figure 5.3 Techem Energy Saving System Adapterm - Data monitoring and transfer services[133]

The data monitoring and transfer services provide intra-communication protocols (i.e. external communication between the gateways and the servers and conducted by

[132] Techem GmbH is a leading global energy service provider for real estate sector and private homeowners in Germany. https://www.techem.de/

[133] https://www.techem.com/products-services/energy-saving-system-adapterm.html

GPRS/Ethernet) about building energy information, which consist of heating energy consumption, cold and hot water consumption. The radio heat cost allocators installed in each radiator of each room are responsible for collecting the room temperature data, while the radio flow temperature sensor for collecting the heating systems' flow temperature data. Both data are gathered (1a and 1b) by the data collector, which based on the gathered data determines the total heat demand in the buildings. Meanwhile, the outdoor temperature is measured via an outdoor temperature sensor and sent to the data collector (2) by adapter module. Based on all received information, data collector calculates whether there is an oversupply of heat in the building or not. If the building is determined as overheated, data collector will send a correction value for reduction of the flow temperature to the adapterm module (3), which then will lower the flow temperature to its optimal level (4). The operation control centre via radio remote access (5) ensures an efficient and proper operation of the adapterm system, and households receive information about energy savings by adapterm via monthly reports (6)[134].

In brief, the adapterm energy system of Techem is frequently optimising the heating curve of the central heating system to continuously save energy using and calculating the temperature information from heat cost allocator through radio frequency (RF). Once occupants are reducing the radiator temperature in their dwellings, the adapterm system can automatically detect this behaviour and constantly communicate with the control panel of the central heating system and optimizing the heating curve. The general functionality and maintenance information of the heating system and adapterm system can be transmitted to the service technician and building administrator, therefore which can receive the daily saving information of energy and CO_2 emission (BECA: The BECA service specification 2012).

EUAS as online service in the light of energy users ensures the occupants to know about their energy consumption at any time. It aimed to make the occupants beware of the impacts of energy-consuming behaviour on the amount of energy consumption and bills. Online service as the main channel allowed occupants to access a user-portal to check the energy consumption by themselves. It is worth noting that the comparison function of user-portal enable occupants to compare their current energy consumption with the previous months, therefore, the impacts of the change of their energy-related behaviour on their energy consumption and bills would be observed more intuitively and thus acknowledged by occupants more effectively.

[134] Product Information on Adapterm, https://www.techem.com/products_services/energy_saving_system_adapterm.html

Fig. 5.4 illustrates the work model of EUAS. The final energy consumption data car provided for users in dwelling-wise and monthly. Fig. 5.5 is a sample of user-portal providing household its monthly energy consumption from September 2011 to August 2012 (red bar) and the monthly consumption of last year, i.e. from September 2010 to August 2011 (blue line), for comparison. In addition, more information services work in paper-wise, such as brochures, and in the way of technical guidance by professionally trained staffs, together with technical interventions. Fig. 5.5 gives an example of access to inquiry of energy consumption via web-based approach (source: Techem).

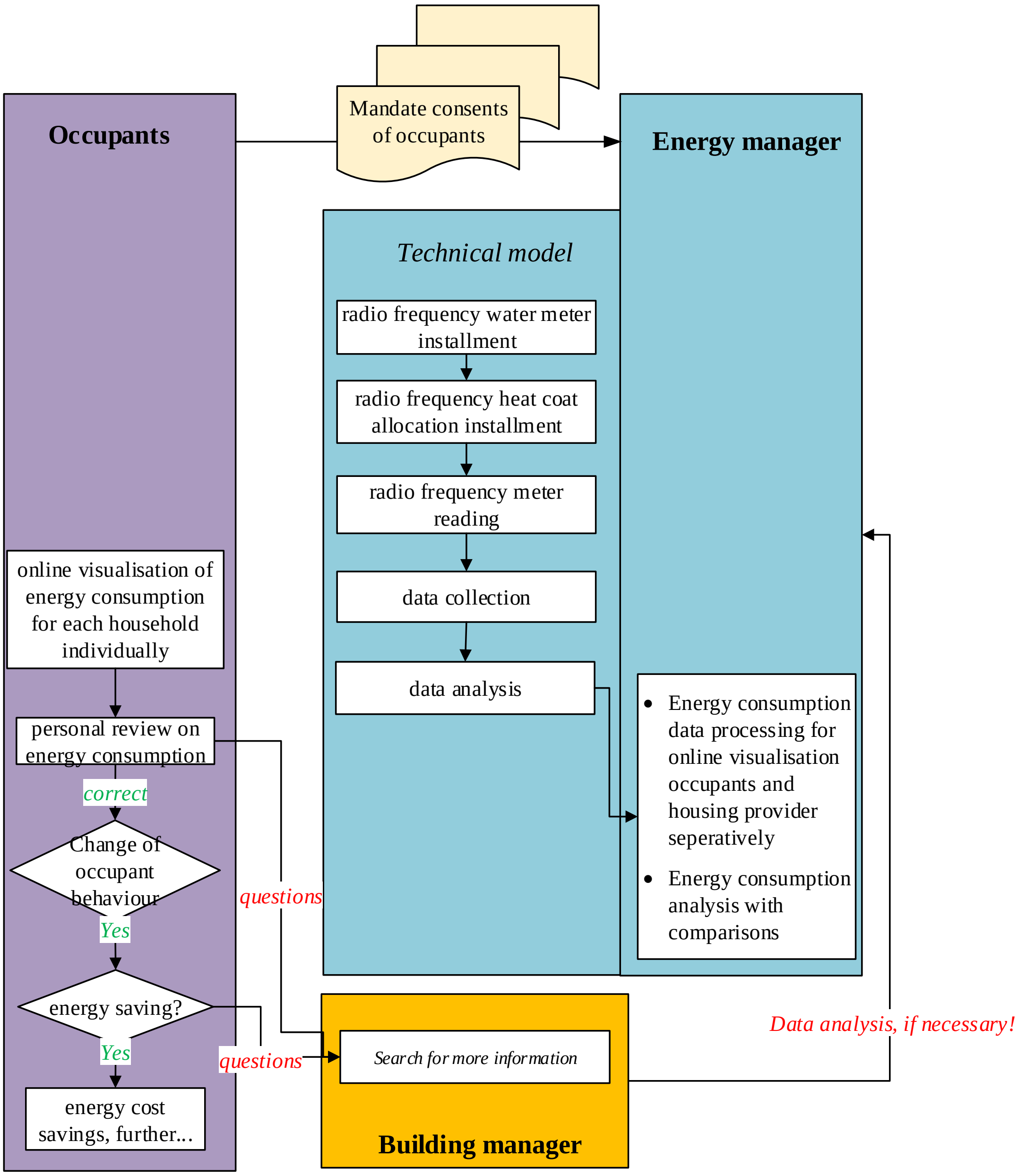


Figure 5.4 EUAS work process model

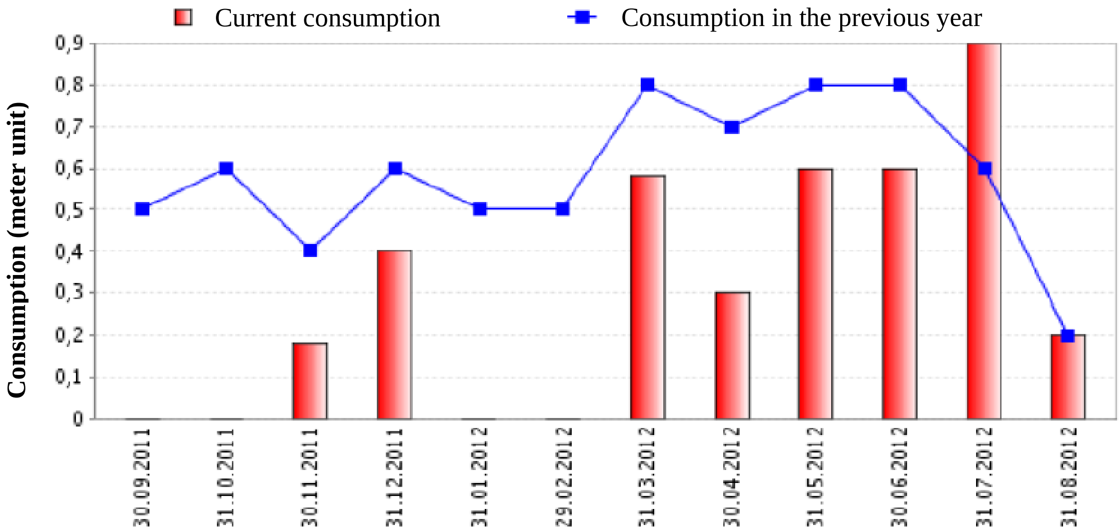


Figure 5.5 Access to individual energy consumption through web-portal

5.1.4 Characteristics of occupant behaviours

The basic information of occupants was partly provided by administrative sources (e.g., address, name), but the main characteristics on their energy-consuming behaviour and awareness, as well as willing to response the assessment and optimization initiatives, were achieved by the way of surveying with questionnaires. Table 5.4 illustrates the main content of questionnaires for acknowledging the characteristics of occupant behaviour in this case.

Table 5.4 Energy-related attitudes and behaviours of occupants

Categories	**Questions**
Attitudes	- Be aware of the common room temperature - Be interested in energy saving information - Be care of energy efficiency of household appliances by purchasing - Be care of the figures on the energy bill - Be aware of the impact of individual behaviour on environmental protection - Be ready for compromise of living comfort due to lowering room temperature for energy saving - Be confident in own available knowledges on residential energy conservation - The significant motivation to change attitudes and behaviours: • to save money

	• to contribute to environmental protection • or both - Be satisfied with Web-Portal for accessing individual energy consumption data
Behaviours	- Behaviour on radiators in winter: • turn off the radiators by opening windows • turn down the radiators by leaving room unoccupied - Behaviour on ventilation: • the frequency of manual room ventilation - Behaviour on room lighting: • turn off the light in the unoccupied rooms - Behaviour on household appliances: • turn off TV and other appliances when leaving home • unplug chargers from the mains or leaving in Stand-by • laundry or dishwasher until fully loaded • tumble dry or natural dry - others like wash hand with cold water, more shower than bath

The survey process was conducted in two stages: pre- and post-survey of occupant behaviours, which collected the information about changes of energy awareness and behaviours before and after implementing energy-saving services. Between the two stages survey a supplementary survey (i.e. midterm survey) was conducted in the way of conversational interview for encouraging more occupants to engage in energy-saving activities. Through the midterm survey, the user experiences on Web-portal and the optimization potential of this service were grasped.

The level of attitudes, consciousness and behaviour of occupants towards residential energy conservation differentiate with each other relating to the different social background. A relative low participation rate in this case was attributed to the occupant group consisting mainly of old and low educational and income level households, i.e. 50-year-old as the average participants' age and most of them with only primary/secondary school leaving qualification. Meanwhile, more than one third of them have immigration background that restricts their German language level, particularly by understanding the survey questionnaires. Fig. 5.6-5.9 illustrate the basic information about the social background of investigated occupants.

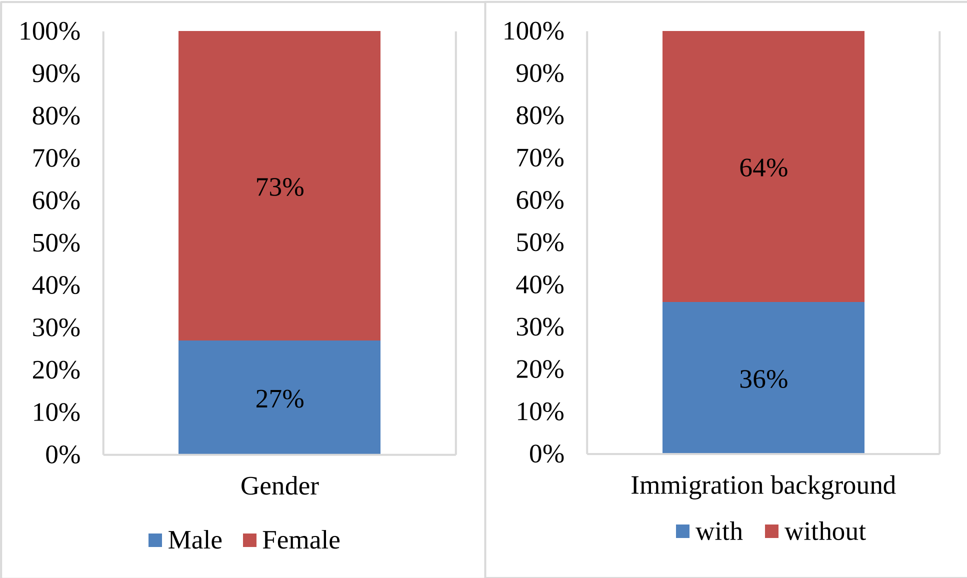


Figure 5.6 Gender and immigration ratio of investigated occupants in case building

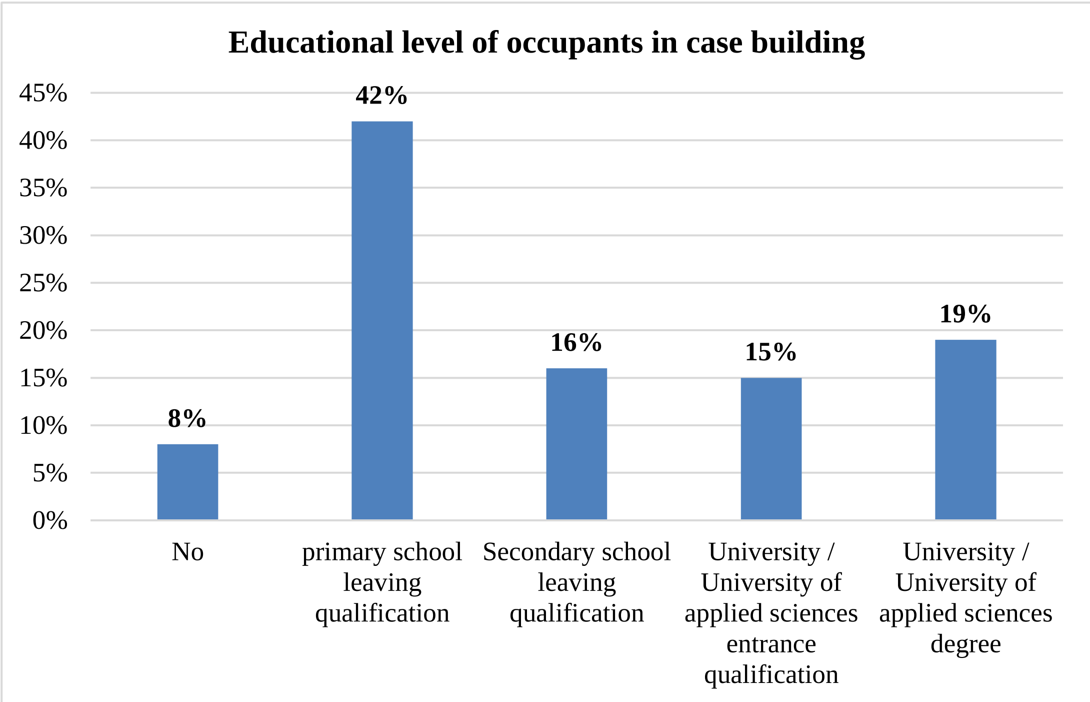


Figure 5.7 Educational level of investigated occupants in case building

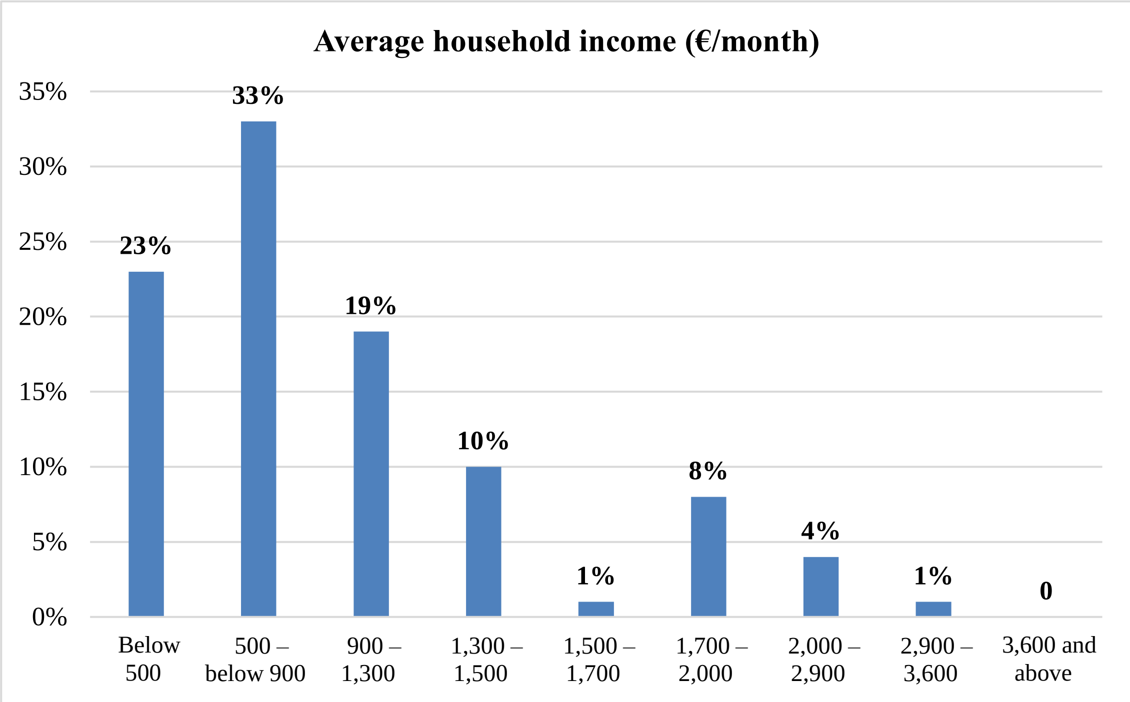


Figure 5.8 Average income per month of investigated household (€/month)

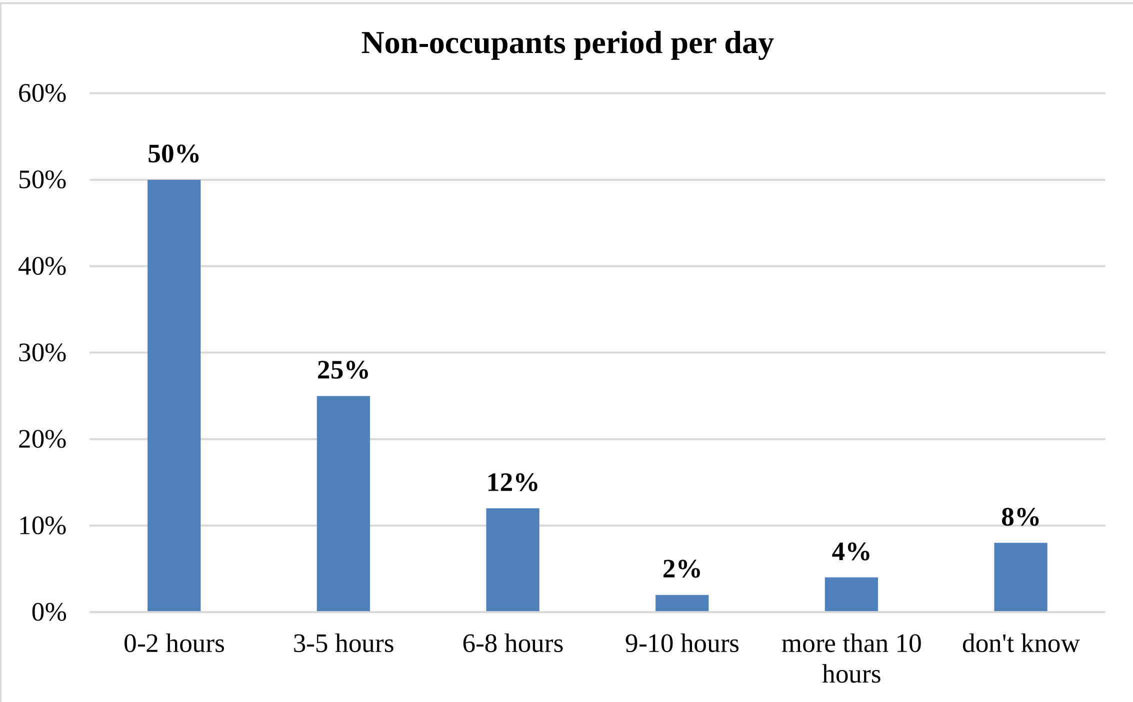


Figure 5.9 Non-occupancy per day of occupants in case building

According to the survey on energy-related behaviours before ESMs implementation, some prevalent features indicated that the interaction between occupants and heating system (i.e. thermal radiator) and electrical appliances appeared not so positive. Only half of investigated occupants expressed that they turned the heating down when they leave a room unused or they leave their home for a long time, or turned off the heating when they open the windows. Only 58% of occupants switched off the electrical appliances with stand-by function when they finished using. About three quarter of occupants used warm water to wash hands rather than cold water. Since the survey results came from the self-reported daily behaviours of occupants, they might remain a certain bias with their real performance by home energy use. Therefore, it is not surprising that the actual energy-using behaviour might be worse than they reported.

In addition, according to survey results in this case, it was found that an intrinsic motivation of environmental protection and high level of ecological awareness failed to result in a high response rate to survey and also to the Web-portal service, and did not always result in energy-saving behaviours. Some potential barriers could be identified, for example, the availability of energy-saving information, affordable households' expenditure, and active information exchange or interaction with neighbours or in communities etc. Some occupants felt unconfident that the portal or their individual engagement could contribute to environmental protection. Some households thought that the Web-portal service was not necessary, because the available information (e.g., energy bills) was sufficient for them, or they had alternative channels to learn more about energy saving issues. However, there were still positive feedback on the portal service from some households.

Another notable feature was about the domestic hot water consuming. It found that the baseline DHW consumption (before ESMs implementation) had more impacts on changing occupant behaviours than the subjective energy saving norms of occupants themselves. Nevertheless, the energy saving norms showed also positive influence. In brief, the energy saving norm should be in combination with further stimulating factors, such as energy saving campaigns, more collective energy-saving activities, so as to be a stronger driver for the achievement of savings. (Kang et al. 2012)

It was worth to note that the participation in surveys must be on the voluntary basis. Therefore, repeated visits or information letters to households were made as necessary to strive for more occupants and thus gathering sufficient data for a sophisticated analysis of impacts of performed services on changing occupants' awareness and behaviour and their energy consumption. Web-portal allowed occupants to visit their energy consumption readily online. The frequency of web-portal visit was recorded by the service provider, which thus could acknowledge occupant awareness towards home energy saving.

Except for questionnaires there were some help services for gaining more individual attitude and feedback on energy saving services from occupants, such as per E-mail, call phone, Infor.-letter or brochure, also Sit-Together-Meeting between building owner, energy providers and households.

5.2 IDA Indoor Climate and Energy (IDA ICE)

Existing building energy simulation tools have achieved a high dynamic dimension of energy consumption through a more accurate analysis of technical integration of building energy system, but the impact of occupant interactions with the control of indoor environment on the building energy performance is overlooked or underestimated. In most traditional simulation, the building energy consumption is considered as a deterministic result, which is conducted as a predicted or suggested value generally during the building design phase. However, a performance gap between the actual consumption and the estimation by the building simulation models emerges after starting the building operation.

IDA Indoor Climate and Energy (IDA ICE) by EQUA[135] is used as the simulation tool in this research work to model the energy performance of investigated social housing buildings with the particular focus on occupant behaviour (OB) impact on home energy consumption. IDA ICE is dynamic multi-zone building energy simulation application with the study of indoor climate of individual zones as well as energy consumption of an entire building (EQUA Simulation AB 2013) using the equation-based language Neutral Model Format, which is a program-independent language for modelling the dynamical systems by using differential algebraic equation (Jarić et al. 2013). Except for a series of comprehensive simulation based on building construction and energy system parameters, IDA ICE simulation provides a high possibility to takes the interaction of occupants into account, for the calculation of building energy balance and indoor environmental quality based on Fanger's thermal comfort indices (e.g., PPD and PMV). Some relevant dependent variables are changing with the interaction of occupants during the simulation process, such as temperatures of indoor air and surface, zone relative humidity, and operating temperature of energy equipment, as well as electrical energy for lighting that takes the daylight level and shading devices and illumination requirement of occupants into account.

5.3 Simulation models

Simulation models of the case building were based on the technical data and occupants information, as well as the climate and building geometry information etc. Fig. 5.10-11 illustrates the building model with IDA ICE.

[135] https://www.equa.se/de/

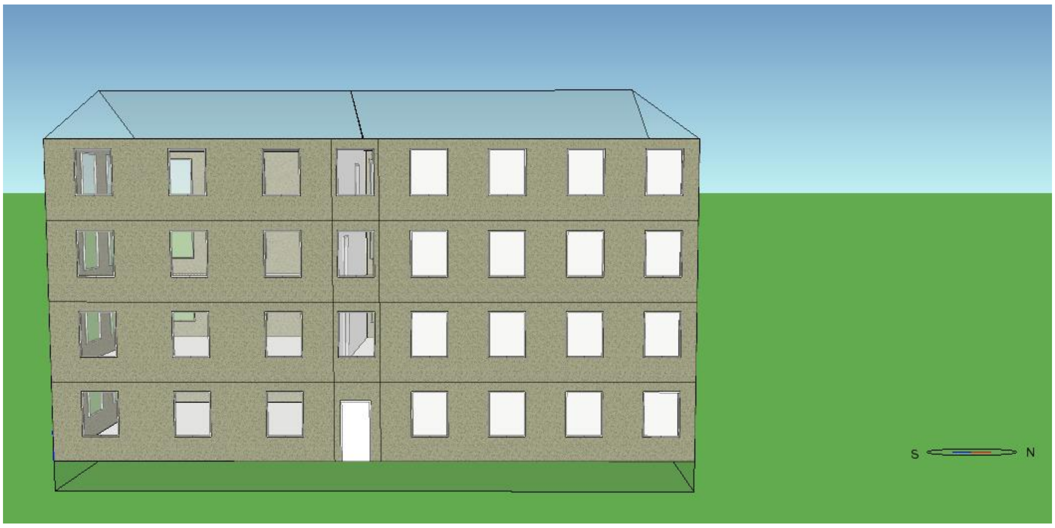


Figure 5.10 Building model in IDA ICE

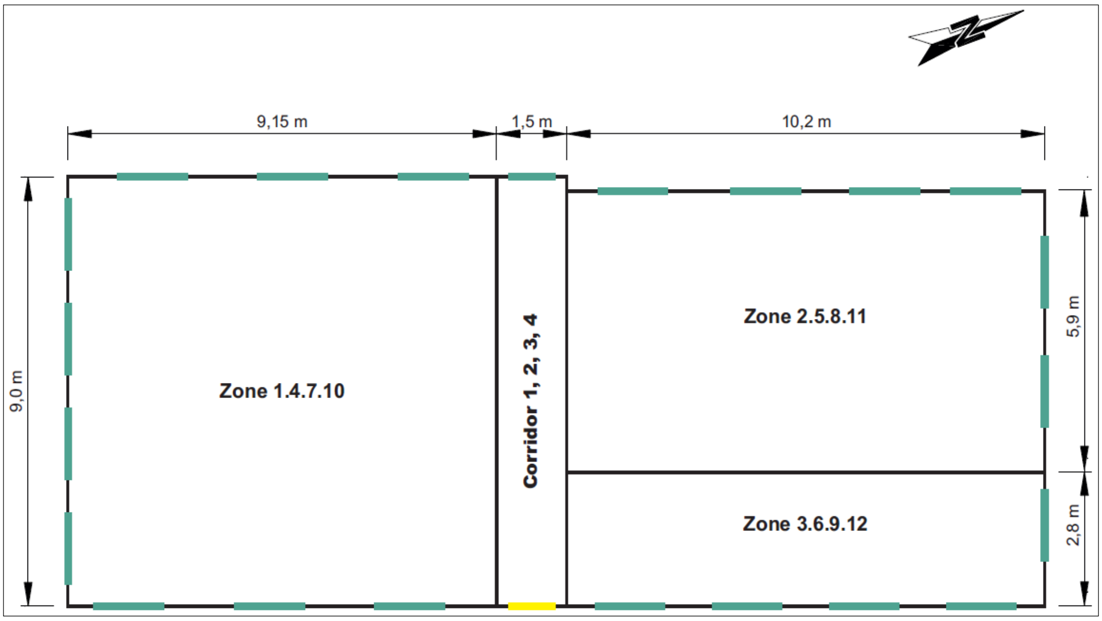


Figure 5.11 Layout of residential units

5.3.1 Parameters identification

Table 5.5 indicates the energy-related building information. Owing to data protection, some of these data were based on the general information of residential building in the same year of construction 1949-1968 in Germany (Loga et al. 2004), which worked as basic condition of simulation process.

Table 5.5 Information of energy-related construction elements of case building

Construction elements	**Materials**	**Thickness [cm]**	**U-value [W/(m²·K)]**
External walls	Light brickwork made of (from inner to outer): Hollow blocks Grid tiles Aerated concrete	36	1.4
Top floor ceilings	(from inner to outer): Plaster Concrete ceiling Cement screed	24	2.0
Roof	(from inner to outer): Plaster Reinforced concrete ceiling Mineral fibre Cement screed	21	1.1
Internal floors	(from inner to outer): Plaster Reinforced concrete ceiling Mineral fibre Cement screed	24	1.3
Windows	2 pane insulating glazing (with SHGC-value g_F = 0,75 Solar transmittance T = 0.7 Visible transmittance T_{vis} = 0.81 Internal emissivity: 0.837; External emissivity: 0.837)	4-12-4 (mm)	2.9
Door construction	(from inner to outer): Wood Aluminium Light insulation Aluminium Wood	0.035	1.085
Window shading	No integrated shading	-	-

The data about energy system generally come from the standard values of building energy system in the same building age (Loga et al. 2004, p.27), as Table 5.6 illustrated. It works as the basic input for simulation.

Table 5.6 Standard parameters of energy equipment of case building

Space heating delivery			**Areal heat energy losses**	
Heating system in continuous operating module (Central heating system, heating with electricity)			$q_{H,\,ce}$ = 3.3 kWh/(m^{2}a)	
Individual stoves in interval operation module (temporarily under-supply, normally lower space temperature than central heating)			$q_{H,\,ce}$ = 0 kWh/(m^{2}a)	
Heat protection standard of heating distribution				
Thermal insulation piping "moderate"[136]				
Area[137]	Installation type	Thermal protection	f_a[138]	U_R
V: horizontal distribution	Under the basement ceiling	Moderate insulation	1.00	0.4 W/(m^{2}K)
S: string lines	Under the plaster of external wall	Uninsulated	0.48	1.4 W/(m^{2}K)
A: connection lines	Under the plaster of external wall	Uninsulated	0.10	1.0 W/(m^{2}K)
Heat protection standard of hot water distribution				
Thermal insulation piping "according to HeizAnlV[139]"				
Area	Installation type	Thermal protection	f_a	U_R
V: horizontal distribution	Under the basement ceiling	Moderate insulation	1.00	0.4 W/(m^{2}K)
S: string lines	Under the plaster of inner wall or shaft	Uninsulated	0.15	1.4 W/(m^{2}K)
A: connection lines	Under the plaster of inner wall	Uninsulated	0.15	1.4 W/(m^{2}K)

[136] Piping networks whose insulation does not conform to the standard of HeizAnlV 1978/1986 or EnEV: Pipeline networks built before 1978 and not completely modernized.
[137] V: horizontal Verteilung; S: Strangleitungen; A: Anbindeleitungen (German).
[138] f_a: area percentage, A_a/A.
[139] HeizAnlV: Heizungsanlagen-Verordnung, which is a German ordinance about the provisions on energy saving and regulations for low-temperature boilers and thermostatic valves.

Table 5.7 The main energy sources of the case building

Energy source modes		
	Application	Percentage
Electricity	- Household appliances - Cooling	100% 100%
Gas	Heating	100%
Oil	-	-
District heat	-	-
Wood	-	-
other	-	-

The thermal bridges influence building heating performance significantly, which are the important instrument to identify the heat losses from the detailed positions of the building construction. For the simulation model of case building, a fixed value of 0.1 W/(m²·K) can be used for calculation of the thermal bridges, also according to suggestion of EnEV 2006 for existing residential building.

In addition, the infiltration, pressure, and extra energy loss and gain from external and internal sources influence the residential energy consumption. These factors are considered as natural intervention, however, they are affected by and interacted with occupant behaviour. For example, the infiltration is determined by the air change rate that is influenced by not only the air pressure, the difference of indoor/outdoor temperature and relative humidity, but also the living habits of residents. The German norms about ventilation in residential building (DIN 1946-6 and DIN 4108-2) regulate that the mean ventilation value of residential dwelling or house shall be 0.5/h, which means, room/house air has to be totally exchanged every two hours. However, in many normal buildings in Germany only 0.2-0.3 h^{-1} could be achieved because some people overestimate the energy loss through ventilation. In addition, modern designed house/building allows lower ACH because of the high standards on building envelope insulation and ventilation system, such as passive house. Nevertheless, the hygienic requirement limits the minimum air change rate, which shall not be lower than 0.3 h^{-1} to ensure fresh air, avoid the indoor odour problem, and reduce indoor dust and microorganism load and excessive radon concentrations as well as possible. In this case study, these parameters are set for simulation within a reasonable range based on the relevant norms and standards, as showed in Table 5.8.

Table 5.8 General system parameters for modelling

Fixed thermal bridge value	
External walls and inner corner	0.1W/(m²·K)

Ground properties		
Ground model	DIN EN ISO 13370[140]	
Ground layers under basement slab:	Thickness	Thermal conductivity
- Default ground insulation	0.1 m	λ = 0.036 W/(m•K)
- Default soil	1.0 m	λ = 2.0 W/(m•K)
	U-value = 0.29 W/(m²•K)	
Ground layers outside basement walls:	Thickness	Thermal conductivity
	0.1 m	λ = 0.036 W/(m•K)
	1.0 m	λ = 2.0 W/(m•K)
	U-value = 0.29 W/(m²•K)	
Air flow (Infiltration)		
Air change rate	0.3 ACH (building), i.e. the fixed air flow in zones is 0.2017 l/(s · m² external surface) *	
Air velocity in the occupied zone	0.1 m/s[141]	
Extra energy and system parameter		
Operative temperature level **	min: 20°C	
	max: 25°C	
Interior heat gain	100 Wh/(m²•d)	
Distribution of hot water use	0-24 h, from Monday to Sunday	
Average hot water use[142]	35 L/ per occupant and day	

[140] DIN EN ISO 13370: Thermal performance of buildings - Heat transfer via the ground - Calculation methods (ISO 13370:2007). If the ground model ISO 13370 is chosen, IDA ICE will calculate the heat resistance of the outermost layer according to this standard, based on the geometry of case building and the heat conductivity of the outermost layer.

[141] According to DIN EN ISO 7730, air velocity depends on air temperature and turbulence rate and also on the presence of HVAC system. ISO 7730 gives the limit values of velocity that is depicted as a function of the operative temperature and turbulence intensity. These values are designed to minimize the effect of local discomfort due to draughts, and the suggested values fall in the range of 0.1-0.3 m/s. Large individual differences exist among occupants with regard to their preferred air velocities, therefore the elevated air velocity must be under the direct control of the affected occupants and adjustable in steps no greater than 0.15 m/s, e.g., 0.1 recommended.

[142] http://www.arthurweber.ch/fileadmin/user_upload/Dokumente/Energietechnik/Speicher_und_Wassererw%C3%A4rmer/planungshilfe_waermel_warmw.pdf

DHW temperature	55.0°C
PMV [143](Fanger) level at which occupant wears maximum clothing (DIN EN ISO 7730)	-1
PMV (Fanger) level at which occupant wears minimum clothing (DIN EN ISO 7730)	1
Level of indoor CO_2 concentration	400 ~ 1500 ppm (vol)
Primary energy factors (DIN V 18599-1: 2011-12)	
- Electricity	2.8
- Natural gas	1.1
- Solar energy	1.0
CO_2 emission factors (Loga and Imkeller-Benjes 1997)	
- Electricity	666 g/kWh
- Natural gas	242 g/kWh
Energy prices for private household (Destatis 2018)[144]	
- Electricity	26.36 cent/kWh (in 2012, annual consumption 2500 kWh ~ 5000 kWh) Fixed cost is assumed as 132.90 Euro/year[145]
- Natural gas	6.42 cent/kWh (in 2012, annual consumption 20 Gigajoules ~ 200 Gigajoules)
Average activity level	2 ~ 2.5 MET[146] (Jette et al. 1990)
Clothing index[147]	0.85±0.25 CLO (Default value in IDA ICE)
Lighting characteristics	

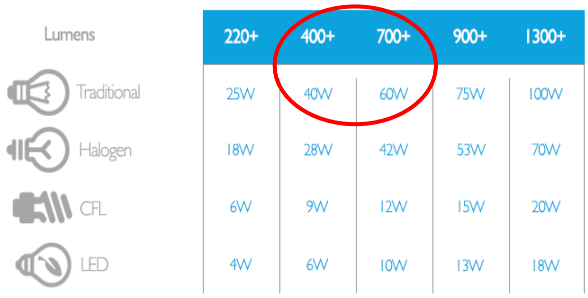
[143] PMV=Predicted Mean Vote. PMV model was developed by P.O. Fanger using heat-balance equations and empirical studies about skin temperature to define comfort, e.g., the thermal sensation is set on a seven-point scale from cold (-3) to hot (+3), see appendix 8.

[144] https://www.destatis.de/DE/Publikationen/Thematisch/Preise/Energiepreise/Energiepreisentwick-lungPDF_5619001.pdf?__blob=publicationFile

[145] According to suggestion by energy provider ENTEGA GmbH depending on the building position and average annual household electricity consumption.(https://verivox.de/power/)

[146] Activity levels (MET), see appendix 8.

[147] The amount of clothing has a large influence on the comfort experienced, which is measured with PPD and PMV, and also has some influence on the power emitted by a person. According to ASHRAE Fundamentals, 1 clo equals a heating resistance of 0.155 m^2•K/W.

- Luminous efficacy (lm/W)[148]	 10 ~ 12
- Convective fraction (0 - 1)	0.3

* DIN EN 15251 defines the air change rate of residential building with ventilation system during the occupancy time, 0.35~0.49 l/(s*m^2) (i.e. ACH = 0.5~0.7), see Appendix 11. Because there are not ventilation system installed in the case building, the ACH is smaller than the standard value in DIN EN 15251.
** DIN V 4108-6 defines the set temperature of space as 19°C under the German climate conditions, while according to DIN V 18599-10 it is 20°C. Too high or too low temperatures in a room result in production losses. According to some research using IDA ICE it has been concluded that for operative temperatures between 20 and 25°C no work is regarded as lost (Wyon 2000). Above and below these limits experiments indicate an average loss of 2% in performance per degree.

Simulation aims to find out the sensibility of occupant behaviour (i.e. occupancy and energy-using indoor activities, as well as the preference of thermostat setting-point) that influences home energy consumption and indoor environmental quality. Owing to privacy, it allows installing occupancy sensors neither in each dwelling nor in the entrance of building. Therefore, in order to model the domestic energy consumption more accurately, an occupancy behaviour profile (i.e. occupancy rate and energy-using behaviour and schedules) of each dwelling was designed based on rational assumption, that means, the occupancy behaviour profiles were established mainly based on surveying with questionnaires.

Four scenarios are designed for analysing the extent of impact of the different factors, i.e. heating areas, occupancy rate and behaviour schedules, as well as the preference of thermostat setting-point.

Scenario 1:
Same heating areas, different household size and the resulting diverse occupancy behaviour profiles.

Scenario 2:
Same heating areas and the same household size, different occupant presence and thus resulting schedules of energy-using appliances and lighting.

[148] https://www.lightbulbs-direct.com/article/lumens/

Scenario 3:
Same household size and same occupancy behaviour profiles (i.e. occupant presence and behaviour schedules), different heating areas.

Scenario 4:
Same household but in different thermostat setting-point.

Case building in this study consists of 12 dwellings in three different floor (heating) areas. Table 5.9 introduces the household size and structure of each dwelling, as well as the primary occupant behaviour attributes that are related to all dwellings but depend on their individual requirements too.

Table 5.9 Basic occupancy behaviour profiles

Zone Nr.	**Area (m^2)**	**occupant status**	
		Household size	**Household structure**
Zone 1	82.35	2 Per.	two retirees
Zone 2	60.18	2 Per.	two retirees
Zone 3	28.56	1 Per.	one retiree
Zone 4	82.35	2 Per.	a daughter with full-time job and retired mother
Zone 5	60.18	2 Per.	One young couple, one is full-time employee and another has a part-time job
Zone 6	28.56	1 Per.	One university student
Zone 7	82.35	3 Per.	Three members of family consists of one full-time employee, one housewife and one school-aged child
Zone 8	60.18	1 Per.	A full-time employee
Zone 9	28.56	1 Per.	A part-time employee
Zone 10	82.35	3 Per.	Same like household in zone 7
Zone 11	60.18	2 Per.	Both full-time workers
Zone 12	28.56	1 Per.	Same like zone 6
Corridor 1	13.50	-	-
Corridor 2	13.50	-	-
Corridor 3	13.50	-	-
Corridor 4	13.50	-	-
General occupant behaviour attributes			
Heating	- Occupied rooms temperature on days under 20°C → heating on - Night sleeping → heating off - Leaving dwelling empty → heating off - Outdoor temperature under 12°C → auto. heating on		
Average DHW use	- 11pm - 6 am: 0% - 6 am - 8am: 100%		

probability	- 8 am - 2 pm: 30% - 2 pm - 6 pm: 50% - 6 pm - 11 pm: 75%
Window	- Odour indoor environment, i.e. CO_2 concentration above 1500 ppm → open fully (DIN 1946-2:1994-01)[149] - Occupied room temperature on days under 20°C → close fully - Occupied room temperature on days above 28°C → tilt (≈30% open) - Night sleeping → close fully - Leaving → close fully
Lighting	- Leaving → off - Indoor illumination under 100 lux[150] → on - Indoor illumination over 450 lux → off
Holidays	
- New year: 1. January - Easter Friday: 6 April - Easter Monday: 9 April - International Work Day: 1 May - Ascension Day (Christi Himmelfahrt): 17 May - Pentecost Monday (Pfingstmontag): 28 May - Corpus Christi (Fronleichnam): 7 June - German Unification Day: 3 October - 1. Christmas Day: 25 December - 2. Christmas Day: 26 December	The schedules of holidays are treated as same as of Sunday. In this case study, the holidays refer to public holidays of Federal State Hessen, Germany in 2012.

The schedules of occupancy, lighting and household equipment are presented in Appendix 12. The schedules of occupancy influence the heating energy consumption under the synergy of local weather. The schedules of lighting and electrical household equipment have the main impact on home electricity consumption. Table 5.10-12 describe the percentage of zones with the different schedules, which explain to a certain extent that its connection with energy consumption. For example, a high percentage of occupancy schedule of retirees leads to relatively higher heating energy consumption in the occupied dwellings than that with occupancy schedules of full-time employees, if all occupants turn off their heating when they leave the rooms. Lighting schedules are then affected by

149 DIN 1946-2:1994-01 ("Ventilation and air conditioning; Technical health requirements (VDI ventilation rules)") specifies 1500 ppm as upper limit of indoor CO_2 concentration.

150 https://www.noao.edu/education/QLTkit/ACTIVITY_Documents/Safety/LightLevels_outdoor+indoor.pdf

both the daylighting condition that depends on the weather, and by the illumination requirement that is defined as a simulation configuration between 100 and 450 lux, as well by the dwelling location (e.g., floors). The schedules of household equipment are influenced by the occupancy schedules and individual living habits of occupants, as well as the power of household appliances that are assumed in the schedule configuration.

Table 5.10 Occupant schedules in building zones

Schedule type	Percentage of zones with this schedule (% of total zone area)
Occupancy of retirees	29.14
Occupancy of part-time employee	6.53
Occupancy of full-time employee	35.89
Occupancy of housewife	12.12
Occupancy of school-aged child	12.12
Occupancy of university student	4.20
Total	100

Table 5.11 Lighting schedules in building zones

Schedule type	Percentage of zones with this schedule (% of total zone area)
Lighting schedule of kitchen of retirees	5.27
Lighting schedule of bathroom of retirees	5.27
Lighting schedule of living room of retirees	7.81
Lighting schedule of bedroom of retirees	11.32
Lighting schedule of kitchen of zone 4	2.54
Lighting schedule of bathroom of zone 4	2.54
Lighting schedule of bedroom of zone 4	2.54
Lighting schedule of kitchen of zone 5	4.59
Lighting schedule of bathroom of zone 5	1.85
Lighting schedule of living room of zone 5	1.85
Lighting schedule of bedroom of zone 5	7.42
Lighting schedule of work room of zone 5	1.85
Lighting schedule of kitchen of zone 6	1.76
Lighting schedule of bathroom of zone 6	1.76
Lighting schedule of living room of zone 6	1.76

Lighting schedule of kitchen of zone 7	5.08
Lighting schedule of bath room of zone 7	5.08
Lighting schedule of living room of zone 7	5.08
Lighting schedule of bedroom of zone 7	5.08
Lighting schedule of bedroom of school-aged child	5.08
Lighting schedule of bathroom of zone 8	1.85
Lighting schedule of living room of zone 8	1.85
Lighting schedule of work room of zone 8	1.85
Lighting schedule of bathroom of zone 9	0.88
Lighting schedule of living room of zone 9	0.88
Lighting schedule of kitchen of zone 11	1.85
Lighting schedule of bathroom of zone 11	1.85
Lighting schedule of living room of zone 11	1.85
Lighting schedule of corridors (always on)	1.61
Total	100

Table 5.12 Household equipment schedules in building zones

Schedule type	**Percentage of zones with this schedule (% of total zone area)**
TV schedule of retirees	2.08
Coffee machine schedule of retirees	2.50
Computer schedule of retirees	2.50
Water cooker schedule of retirees	3.70
Cooker schedule of retirees	5.79
Dishwasher of retirees	7.87
TV schedule of zone 4	1.20
Coffee machine schedule of zone 4	1.20
Cooker schedule of zone 4	1.20
Hair dryer schedule of zone 4	2.96
Laptop schedule of zone 4	2.50
TV schedule of zone 5	1.76
Computer schedule of zone 5	0.88
Water cooker schedule of zone 5	1.76
Cooker schedule of zone 5	3.94

Coffee machine schedule of zone 5	3.06
Coffee machine schedule of university student in zone 6	0.83
Water cooker schedule of university student in zone 6	0.83
Cooker schedule of university student in zone 6	0.83
Laptop schedule of university student in zone 6	0.83
TV schedule of zone 7	2.41
Computer schedule of zone 7	2.41
Water cooker schedule of zone 7	2.41
Coffee machine schedule of zone 7	2.41
Cooker schedule of zone 7	4.81
Hair dryer schedule of zone 7	2.41
Water cooker schedule of zone 9	0.42
TV schedule of zone 11	0.88
Computer schedule of zone 11	0.88
Water cooker schedule of zone 11	0.94
Cooker schedule of zone 11	1.76
Hair dryer schedule of zone 11	0.88
Dishwasher of zone 11	0.88
Other equipment (fixed value)	9.58
Standby appliances (always on)	10.00
Washing machine schedule (all)	8.75
Total	100

5.3.2 Assessment criteria and behavioural algorithms

Assessment criteria of simulation results focus on the impacts of occupancy profile on home energy consumption, which base on the analysis of different scenarios defined above. Therefore, the occupant-related indoor environmental elements (e.g., indoor CO_2 concentration, related humidity, and daylighting level) and Fanger‘s thermal comfort were compared among different scenarios, in addition heating and electricity energy consumption, heat balance, as well as occupant satisfaction with thermal environment. Fig. 5.12 depicted the workflow of the modelling system.

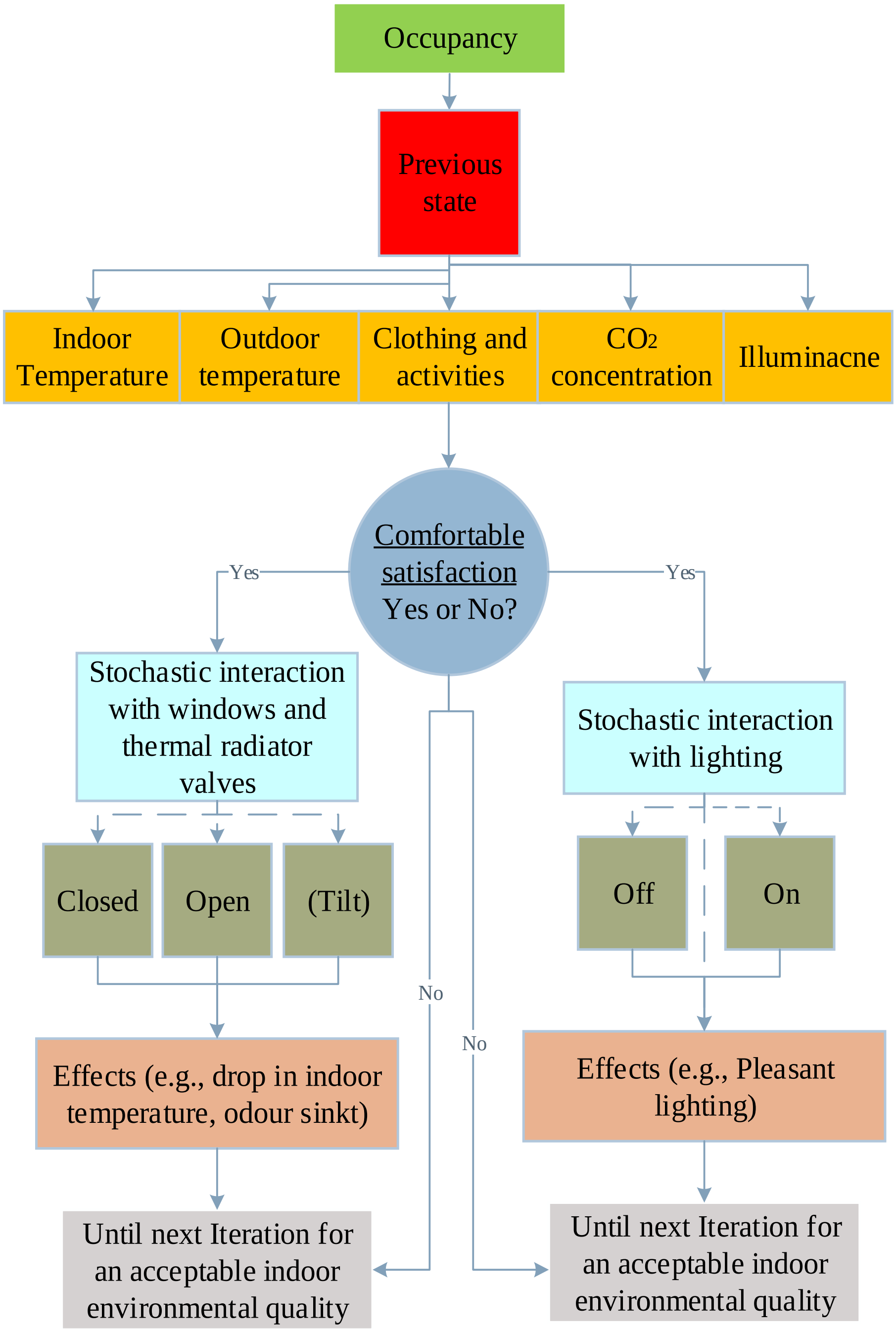


Figure 5.12 Algorithm of occupant behaviours on windows, thermal radiator valves and lighting

5.4 Simulation results

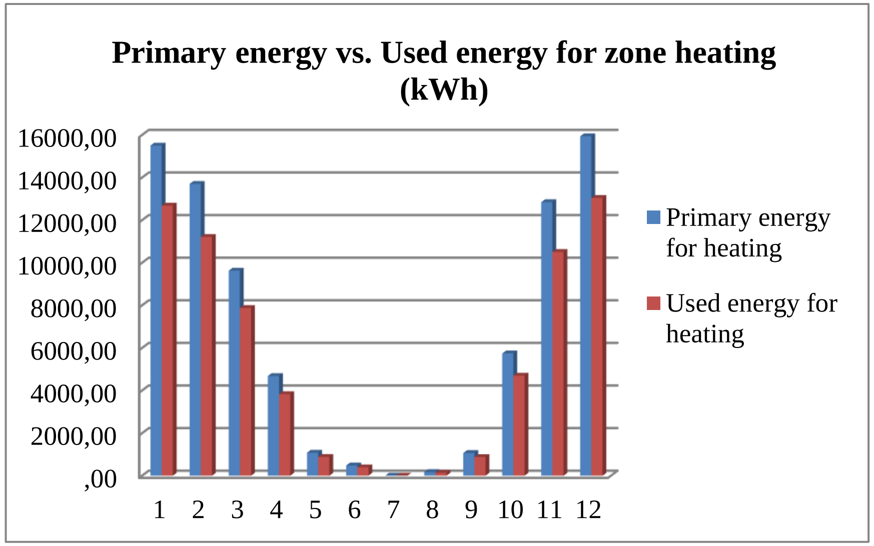
Simulation results referred to energy balance, heat balance, indoor air quality, daylighting level, monthly thermal comfort according to EN 15251 standard, Fanger's comfort indices. These results were in dwelling-wise for comparison. The primary energy was calculated for each month and the energy costs were calculated based on the provided energy prices. Fig. 5.13 gave the comparison of primary energy and final used energy consumption in the whole building and meanwhile monthly delivered energy, CO_2 load and energy costs in building-wise were illustrated in Appendix 13. The details of simulation results in dwelling-wise were illustrated in Appendix 14-17.

5.4.1 Primary energy for the whole building

Building	
Model floor area	736.6 m^2
Model volume	2375.4 m^3
Model envelope area	982.1 m^2
Window/Envelope	14.3%
Average U-value	1.528 W/(m^2*K)
Envelope area per Volume	0.4134 m^2/m^3

Delivered energy									
	Purchased energy		**Peak demand**	**Cost**		**CO_2**		**Primary energy**	
	kWh	**kWh/m²**	**kW**	**Euro**	**Euro /m²**	**kg**	**kg/m²**	**kWh**	**kWh/m²**
Lighting, facility	1827	2.5	0.71	618	0.8	1224	1.7	5144	7.0
Equipment, facility	46759	63.0	39.07	12460	16.9	31141	42.3	130925	177.8
Total facility electric	48586	65.5	39.78	13078		32365		136069	
Fuel heating	73483	99.8	26.52	4718	6.4	17783	24.1	80831	109.7
DHW	34758	47.2	3.96	2231	3.0	8411	11.4	38234	51.9
Total facility fuel	108241	147	30.48	6949		26194		119065	
Total	156827	212.5	70.26	20027		58559		255134	

Used energy (kWh)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	**Total**
Zones heating	12680.0	11211.0	7876.0	3830.0	882.7	393.5	2.2	138.6	873.2	4698.0	10508.0	13040.0	66133.2
(Primary fuel energy for zone heating)	*15497.9*	*13702.7*	*9626.1*	*4681.6*	*1078.9*	*480.9*	*2.7*	*169.4*	*1067.2*	*5742.0*	*12843.6*	*15937.9*	*80830.9*
DHW	2649.0	2478.0	2649.0	2564.0	2649.0	2564.0	2649.0	2649.0	2564.0	2649.0	2564.0	2649.0	31277.0
(Primary fuel energy for DHW)	*3238.4*	*3029.4*	*3238.4*	*3133.9*	*3238.4*	*3133.9*	*3238.4*	*3238.4*	*3133.9*	*3238.4*	*3133.9*	*3238.4*	*38233.8*



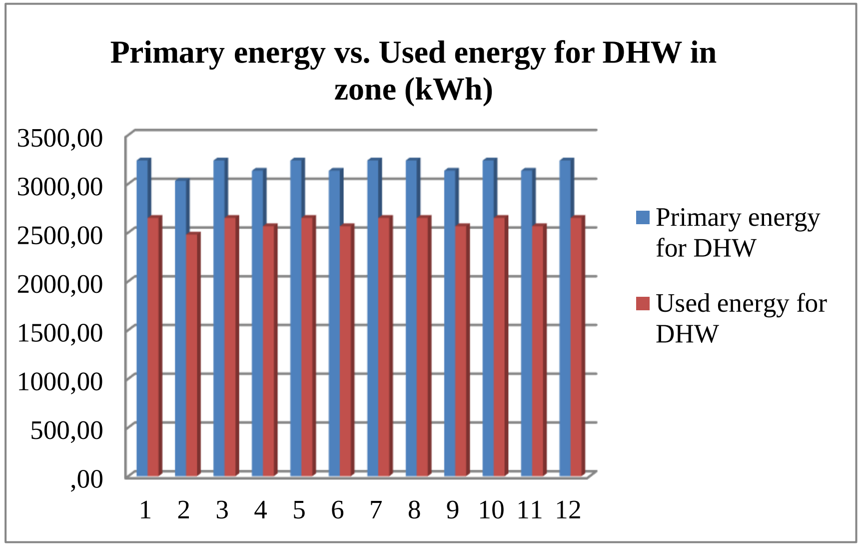


Figure 5.13 Comparison between primary energy and used energy for building heating and DHW supply

5.4.2 Energy balance

Energy balance described how the demanded energy was consumed during a completely heating period, which was supported mainly by the heating system (i.e. local heating units) and affected by the occupancy rate and the corresponding occupant behaviours with lighting and electrical household equipment that dissipated heat into the living areas. The detailed energy balance of each zone/dwelling was presented in Appendix 14.

5.4.3 Heat balance

Heat balance described the heating energy input from different heating sources (e.g., heating units, occupants, direct and diffuse solar energy, electrical equipment and lighting) and output through items (air flows, heat losses through doors and windows, heat loss through walls and floors, heating losses owing to thermal bridges).

Heat from direct and diffuse sunshine is affected by the orientation and size of main window areas; heat from occupants depends on the occupancy rate; heat from the electrical household equipment and lighting is affected by on the one hand the amount of equipment and their power, one the other hand by the using habits and occupancy. Heat losses owing to air flows and thermal bridges or through windows, walls and floors rise along with the increased living areas. The detailed monthly heat balances of each zone were presented in Appendix 15.

5.4.4 Indoor air quality

Indoor air quality refers to basically three evaluation indicators that influence indoor living comfort, i.e. air age (h), CO_2 concentration (ppm, vol) and relative humidity (%). The three evaluation indicators are affected by different occupant schedules, e.g., air age depends not only on the living areas, the main orientation of windows and wind speed, but also on the occupancy schedules and individual ventilation custom. CO_2 concentration strongly depends on the occupancy rate. The impact factors on indoor relative humidity include for example the local weather conditions, the interaction between occupants and window-opening behaviour, as well as other possible indoor behaviours of occupants like shower or laundry etc. The detailed monthly indoor air quality measures of each zone were presented in Appendix 16.

5.4.5 Fanger's comfort indices

Thermal comfort is a very individual index and influenced by many factors, such as metabolic rate, clothing insulation, and air temperature, radiant heat transferred from any surface in a space, air speed, relative humidity and natural ventilation etc. PPD and PMV developed by Fanger are deduced through heat-balance equations and empirical studies about skin temperature. PMV is scaled from cold (-3) to hot (+3), which depends on a particular combination of above mentioned influencing factors. Zero is the ideal PMV value, representing thermal neutrality. ASHRAE Standard 55-2010 (ASHRAE 2010) uses the PPD to set the requirements for indoor thermal conditions, which requires at least 80% of the occupants be satisfied. Appendix 17 presents the Fanger's comfort indices of each zone.

5.5 Sensitivity analysis

The main energy dissipation happens through the building envelope transmission, i.e. through walls, windows and roofs, as well because of thermal bridges of building. Besides, thermal energy loss is also attributable to infiltration and opening. On the contrast, occupants and the equipped household appliances as well as lightings contribute to a rise of indoor temperature as a relatively weak intern thermal source, depending on the occupancy rate and individual metabolic equivalent, and the using schedules of electrical appliances and lighting as well as their power.

The simulation results presented in this chapter contribute to a further understanding of residential energy consumption closely related to characteristics of building construction and energy appliances, individual households, occupants behaviours and awareness.

5.5.1 Sensitivity to occupancy rate

As analysis intention of scenario 1 described, it was proposed to compare the energy demand for heating and household appliances among the dwellings with the same floor/heating areas and domestic electric equipment but different occupancy rate. Zone/dwelling 4 and 7 are suitable for comparison in this scenario. Based on the description of family structure and schedules of both dwellings, the average occupancy rate of dwellings, energy for maintaining the required indoor temperature and acceptable level of moisture, as well supporting the operation of domestic electric appliances complying with schedules were simulated and calculated, as Fig. 5.14-17 depict. The occupancy rate was calculated depending not only on the average indoor duration of each occupant but also more on the total number of occupants in the same zone.

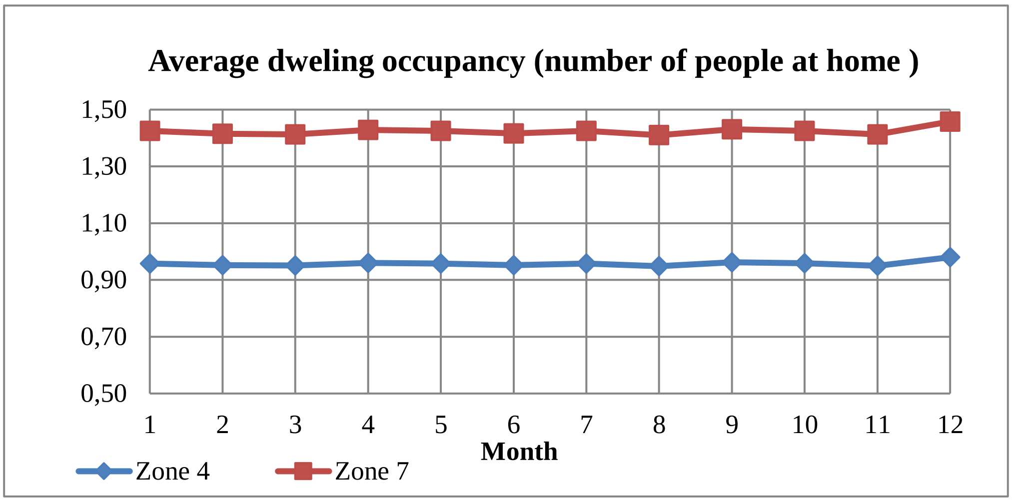
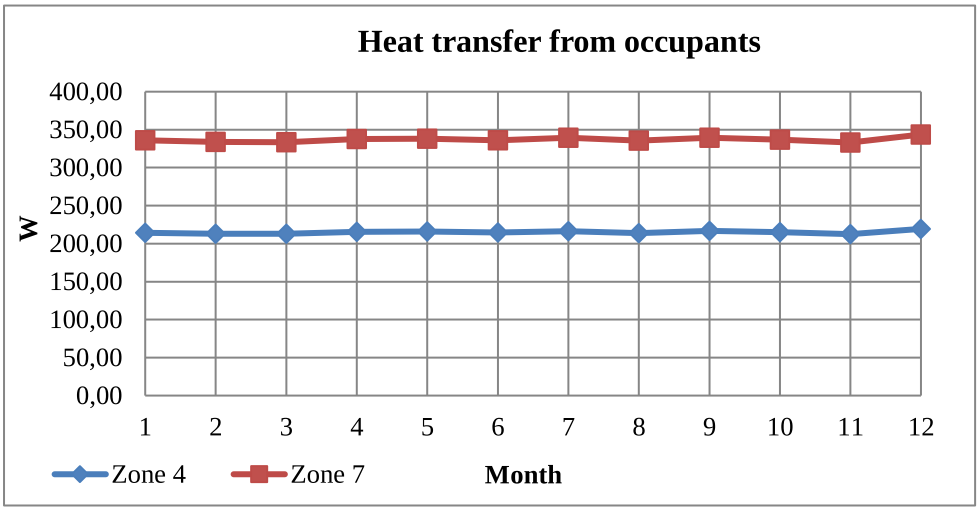
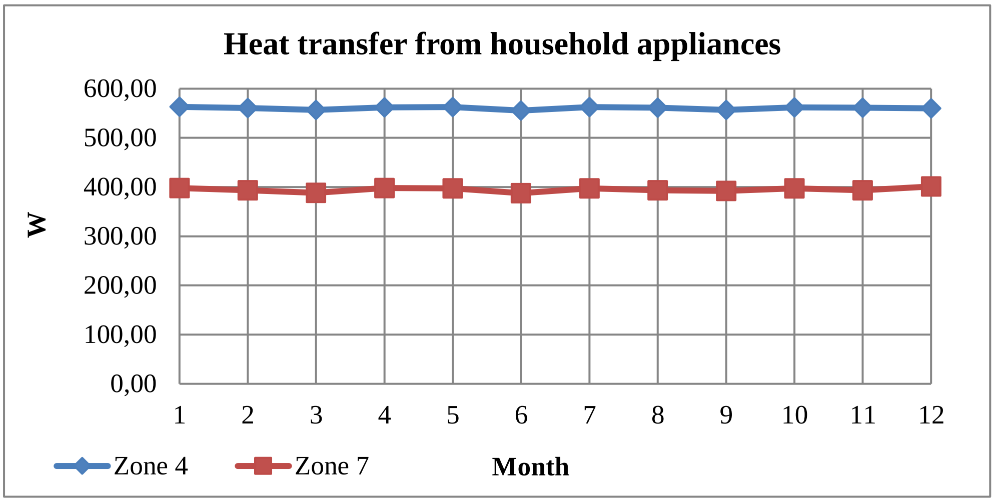


Figure 5.14 Zone occupancy - dwelling 4 vs. dwelling 7

Fig. 5.15 indicated the heat transfer from the potential indoor thermal source. It was taken for granted that heat transfer from occupants in dwelling 7 was more than in dwelling 4 owing to the higher occupancy rate and the slightly higher MET value of occupants in dwellings 7 with 2.2, while retirees in dwellings with 2.0. However, the heat dissipating from electric appliances and lighting was determined principally by using schedules, as Appendix 12 illustrates. A relative long indoor duration of occupants in dwelling 4 could contribute to high heat dissipation from domestic electric appliances and lighting than in dwelling 7, due to higher utilization rate.





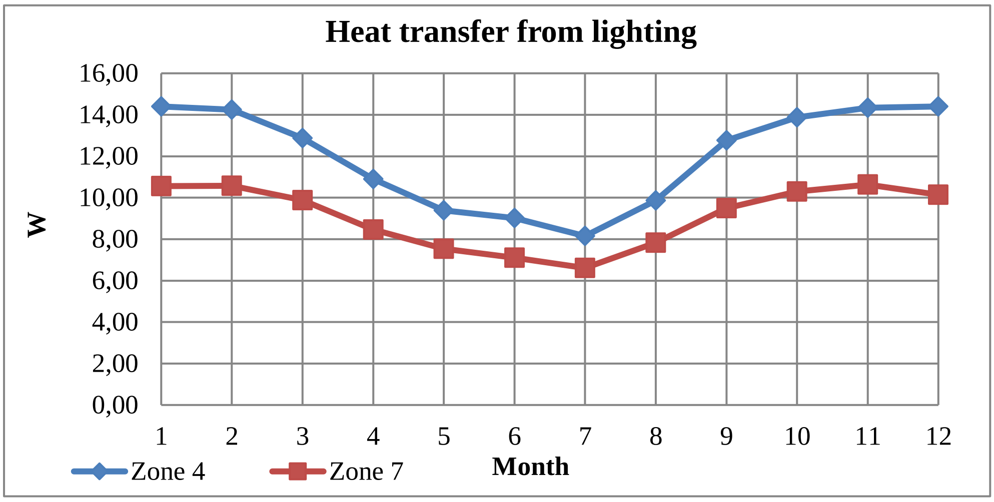
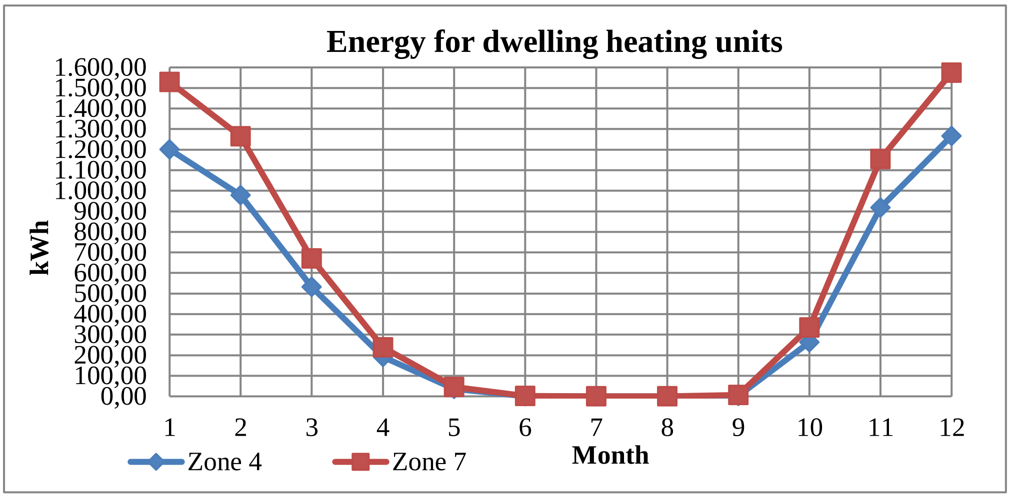
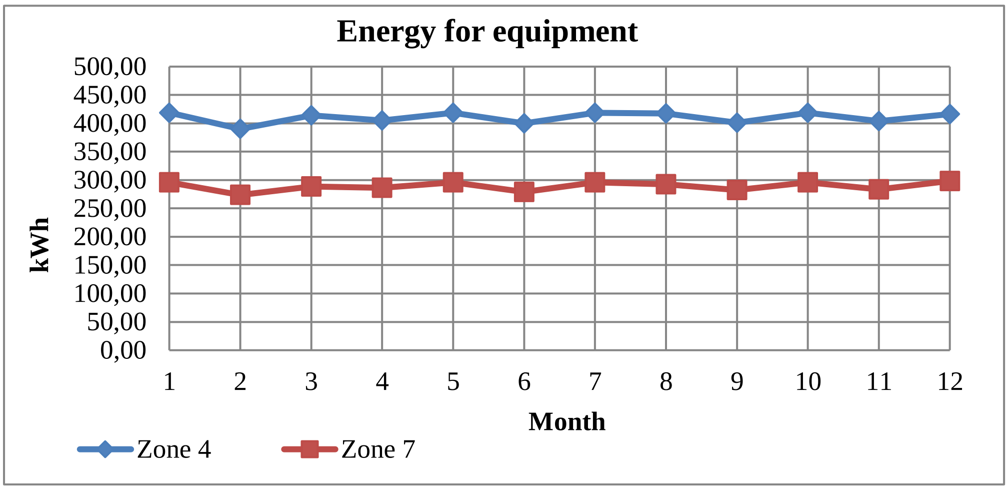


Figure 5.15 Sensibility of heat transfer to occupancy rate and corresponding difference in using schedules

The corresponding energy demand for heating, lighting and appliances were illustrated in Fig. 5.16, which was hard to explain the slight difference in heating energy consumption from the occupancy perspective, because the indoor temperature could be influenced by the floor position that resulted in the difference of wind speed and intensity of sunshine, except for the heating areas, thermal set-points and occupancy rate. However, the electricity consumption for household appliances and lighting were directly affected by the using schedules of occupants.





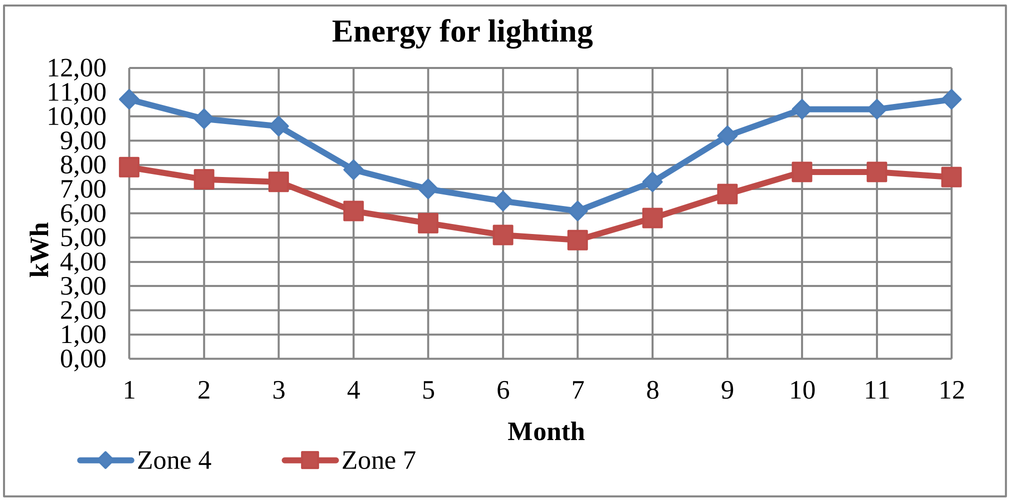


Figure 5.16 Sensibility of energy demand to occupancy rate and schedules

CO_2 concentration in a living unit was normally highest during the night with full-closing windows and full occupancy rate and could sink with often air change. It was therefore understandable that the CO_2 concentration in dwelling 7 with three persons was higher than dwelling 4 with two persons, as Fig. 5.17 showed. A longer and frequenter air change by window-opening in summer might contributing to reducing it at a certain extent.

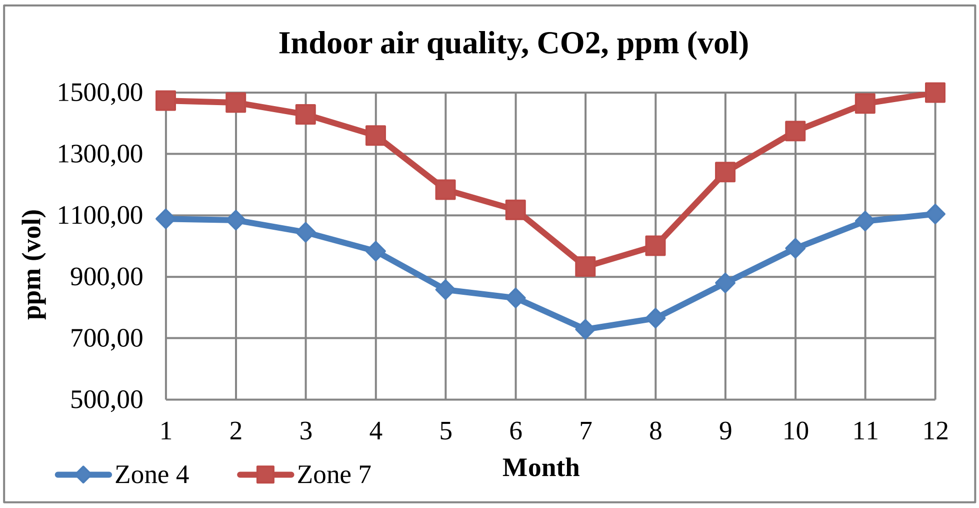


Figure 5.17 Sensibility of indoor CO_2 concentration to occupancy rate and schedules

5.5.2 Sensitivity to energy-using behaviours

Generally, there should be no obvious difference in energy consumption among the dwellings with the same heating areas and room orientation, also with the same family size. However, the influence of energy-related behaviours has been proven not be over-looked. According to the description of scenario 2, it would compare the zone/dwelling 2 and zone/dwelling 5 and zone/dwelling 11.

Two retirees lived in dwelling 2 living, who both spend normally only 3-4 hours per day outside, which influenced to a great extent their schedules of using household electrical appliances, and thus led to a difference in home electricity consumption, indoor air quality and comfort feeling. However, in dwelling 5 a young couple (one was full-time employee, another was part-time employee) spent usually 8 hours outside for work, and dwelling 11 for two full-time workers even more time, where most of their usual energy-using schedules at home were different with the dwelling for retirees. The average zone-occupancy of dwelling 2 and 5 and 11 are 1.0, 0.9 and 0.85 respectively, according to the calculation method of IDA ICE, depicted as Fig. 5.18. Heat balance of each dwelling reflected the most obvious impacts of occupancy rate and schedules on thermal energy among these dwellings.

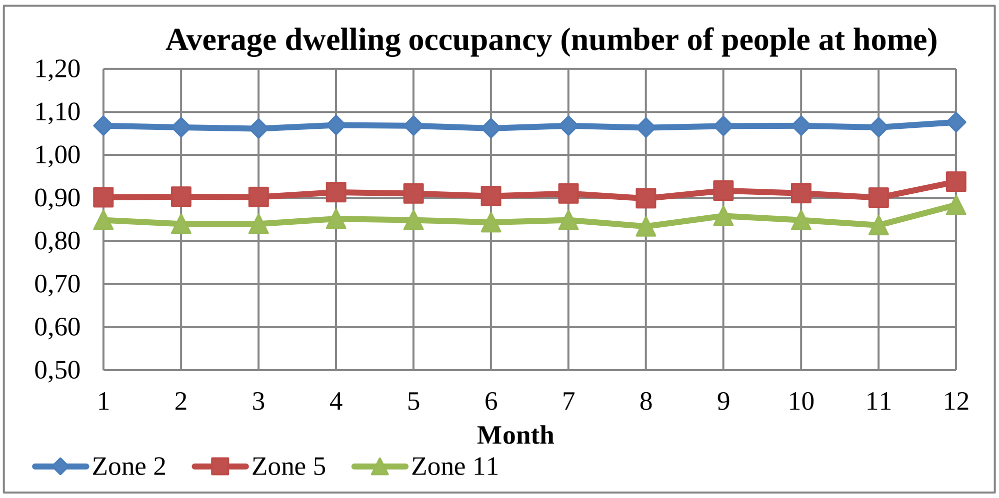
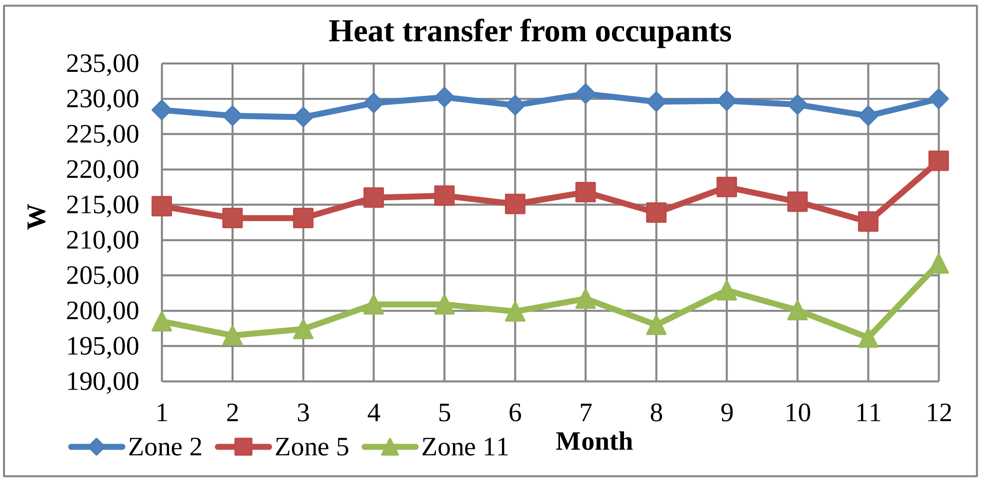
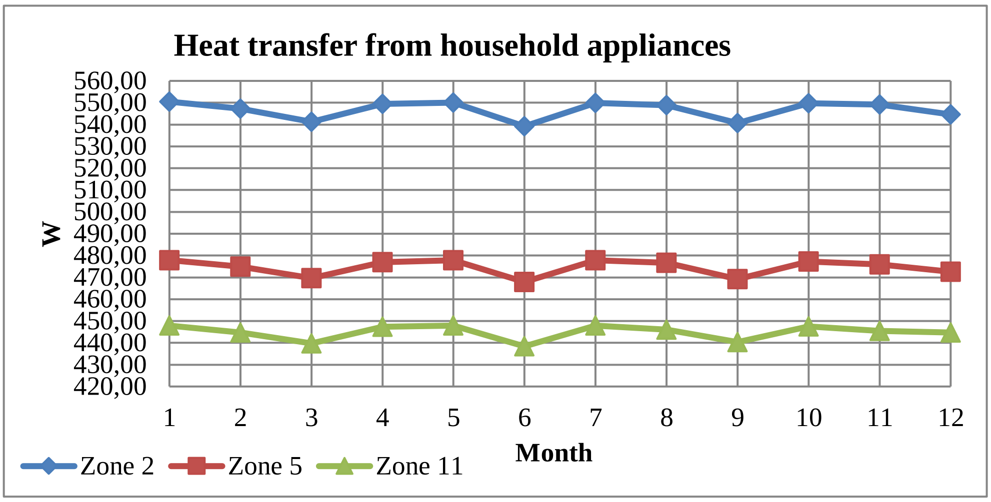


Figure 5.18 Zone occupancy - dwelling 2, 5 and dwelling 7

The average amount of heat from occupants increased obviously along with the average indoor duration of occupants, and owing to the relatively longer indoor duration and thus higher frequency of energy-using behaviour, the demand of electricity for appliances and lighting rise consequentially. Fig. 5.19 illustrated the diversity of heat transfer from occupants, household electrical appliances and lighting among the three households.





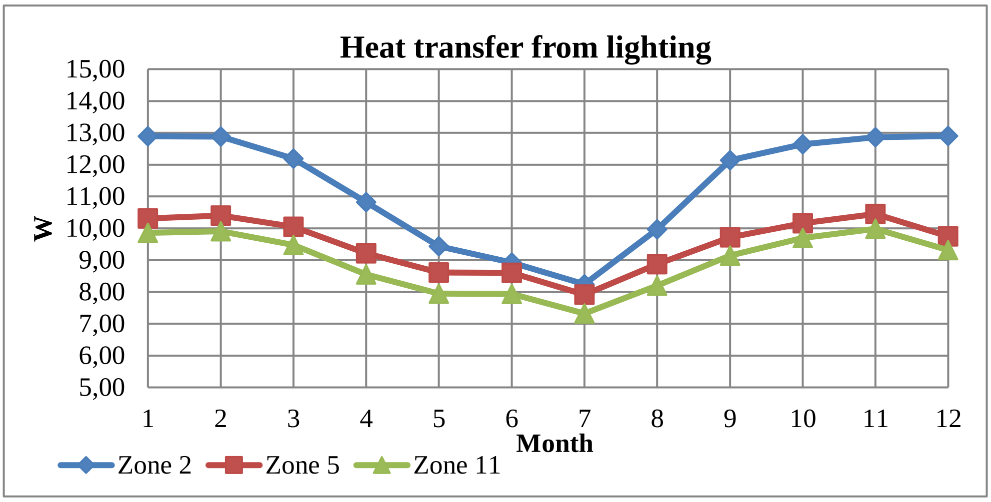
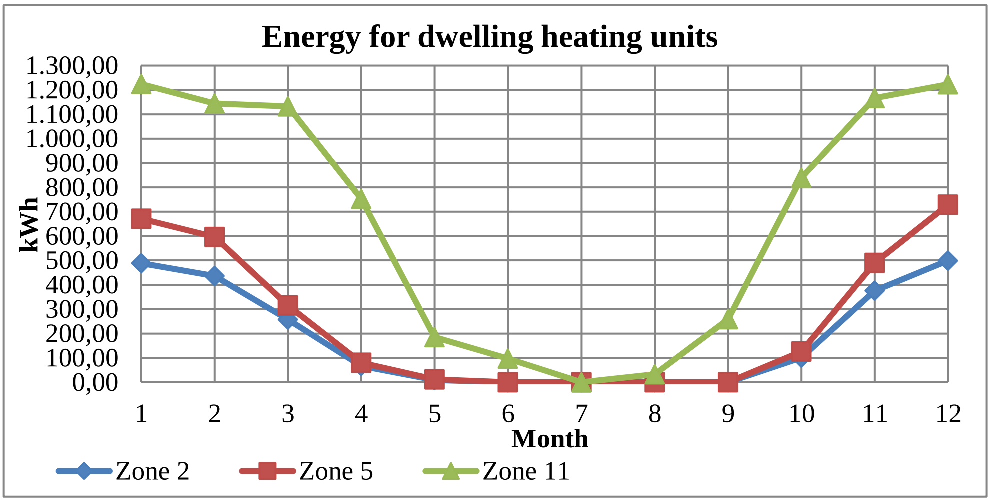
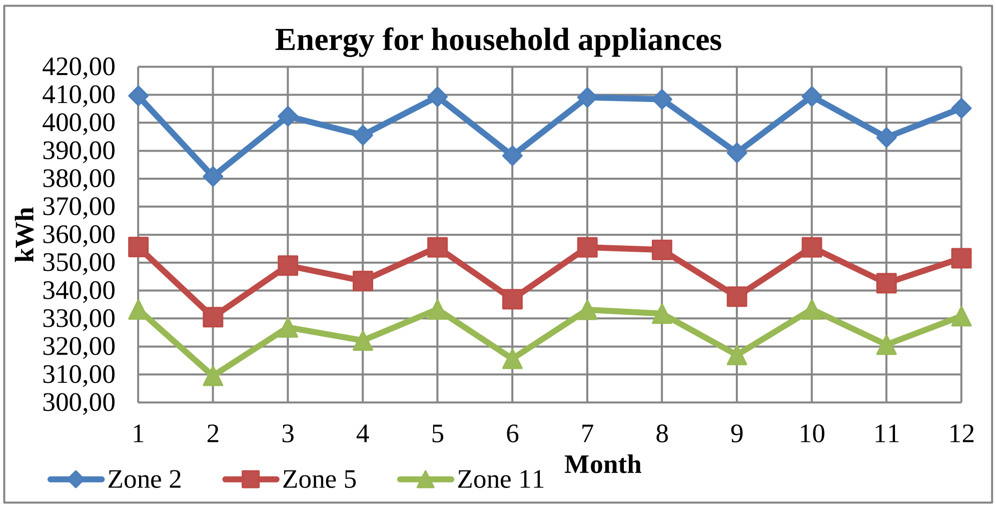


Figure 5.19 Sensibility of heat transfer to occupant behaviour

Fig. 5.20 indicates the energy for heating units, household appliances and lighting. Various factors as before described in scenario 2 could explain the difference in energy demand. Fig. 5.21 depicted the comparison of occupancy rate.





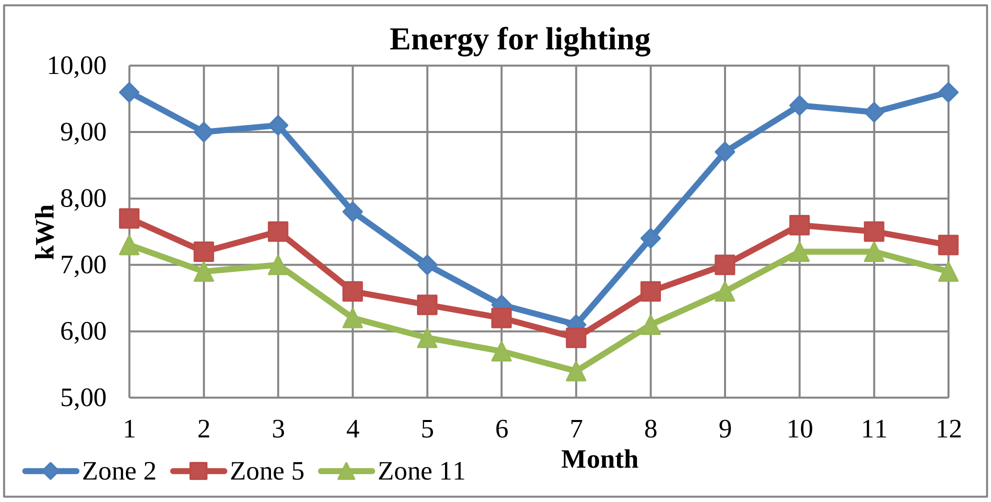


Figure 5.20 Sensibility of energy demand to occupant behaviour

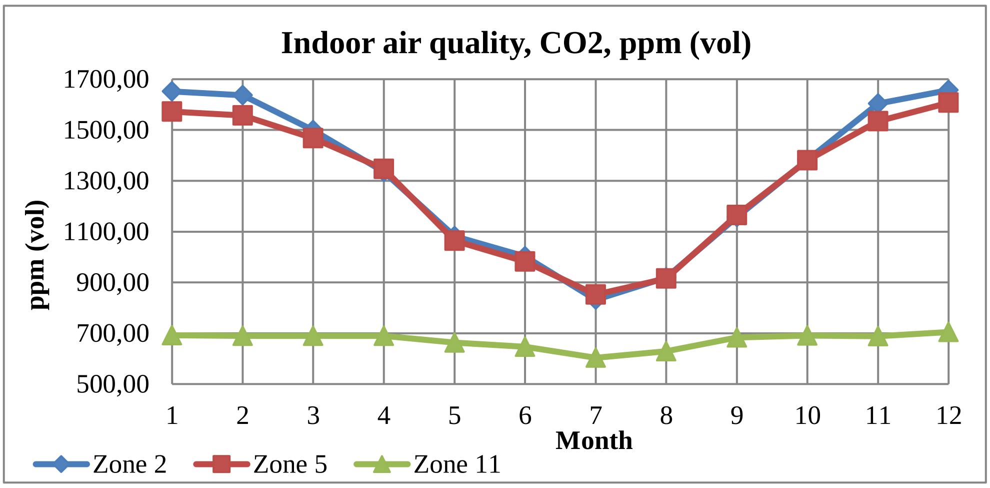
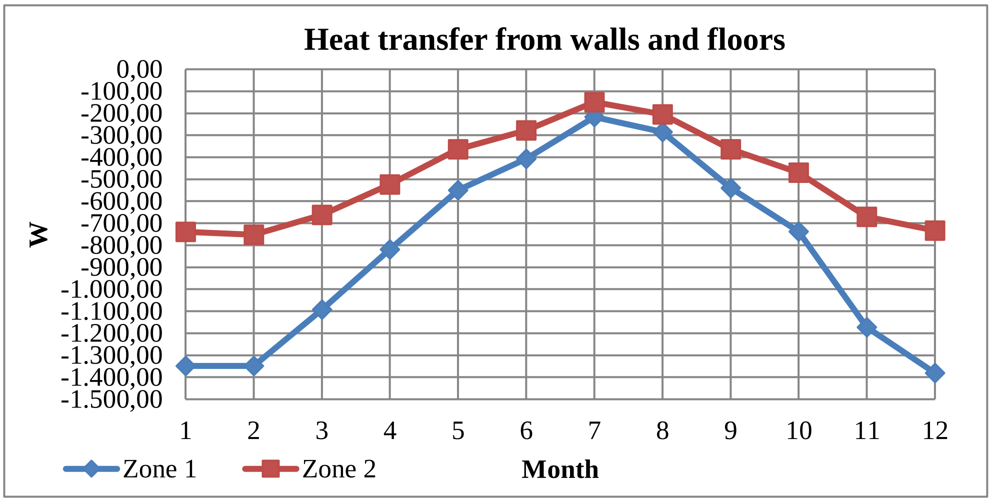


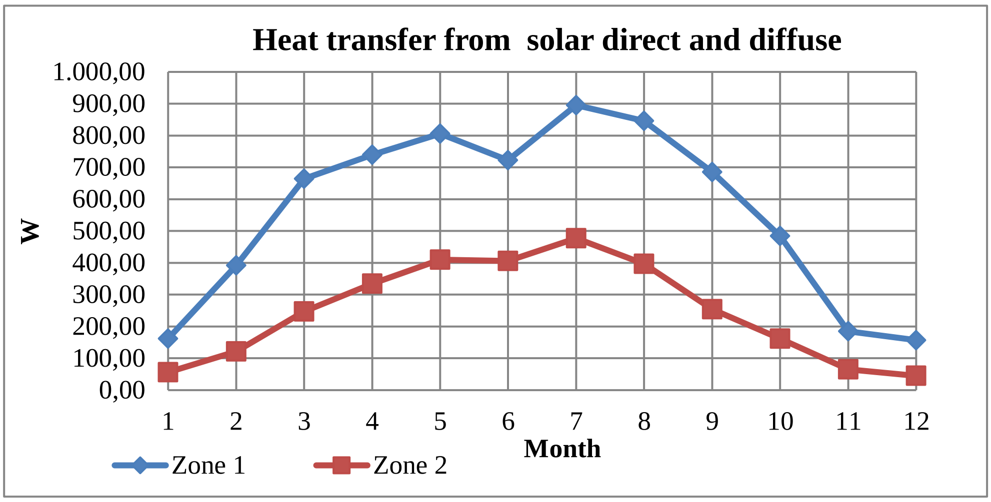
Figure 5.21 Sensibility of indoor CO_2 concentration to occupant behaviours

5.5.3 Sensitivity to floor area and dwelling position

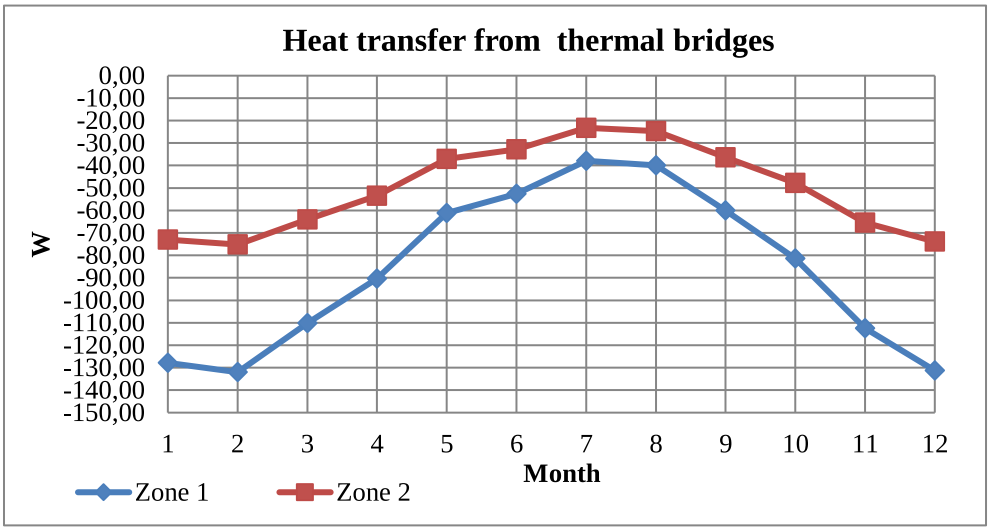
As above indicated, energy demand for household electrical equipment and lighting are influenced strongly by the interaction of occupants. However, heating energy demand depends considerably on air-tightness of building envelope (including windows and openings), where occurs the most likely heat loss in the heating period. The heat gain from occupants, equipment and lighting, as well as solar energy through windows are a relatively little thermal source for the whole heating period. It is worth mentioning that air infiltration and solar heat gain are affected by the position of building and dwellings, and window orientation, among other things, impacts of wind speed and direction, and local rate of insolation and exposure of transparent section, as well as semi-translucent outside surfaces of building or dwellings.

According to scenario 3 described, the comparison was conducted between the zone/dwelling 1 and 2, which both had the same occupant-related conditions (i.e. same occupancy rate and schedules) but different floor areas, i.e. different heating areas and orientation toward daylight and wind direction. The difference could be reflected by a comparison of energy for room heating units, energy loss through the envelope and thermal bridges and infiltration, the heat balance between solar energy gain in summer and heat loss in winter or cold weather, both through windows. Fig. 5.22 illustrated the heat loss and gain through building outside surface, windows and openings, air flows as well. It was calculated that heat loss in most cold weather was almost double in dwelling 1 than in dwelling 2 due to the much smaller floor areas of dwelling 2 than of dwelling 1.

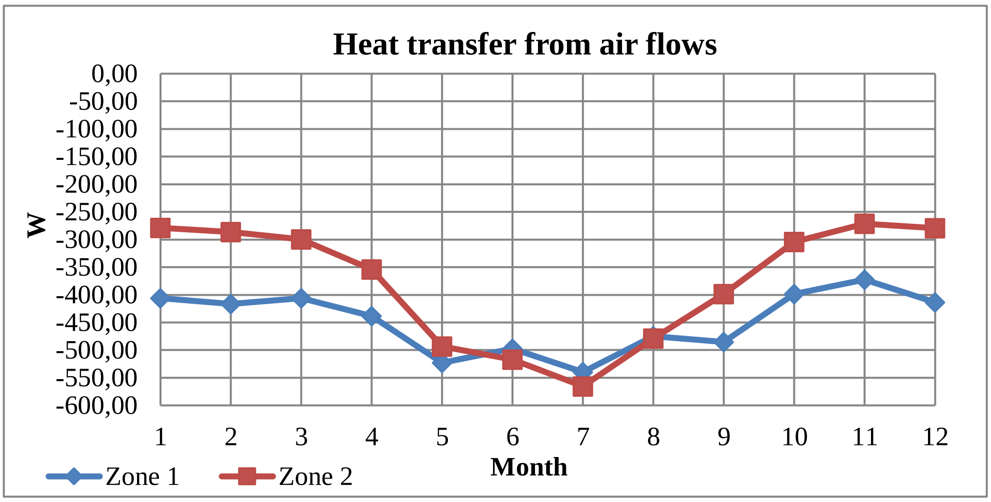




Heat transfer from solar direct and diffuse
W
1.000,00
900,00
800,00
700,00
600,00
500,00
400,00
300,00
200,00
100,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12
Month
Zone 1
Zone 2



Heat transfer from thermal bridges
W
0,00
-10,00
-20,00
-30,00
-40,00
-50,00
-60,00
-70,00
-80,00
-90,00
-100,00
-110,00
-120,00
-130,00
-140,00
-150,00
1 2 3 4 5 6 7 8 9 10 11 12
Month
Zone 1
Zone 2



Heat transfer from air flows
W
0,00
-50,00
-100,00
-150,00
-200,00
-250,00
-300,00
-350,00
-400,00
-450,00
-500,00
-550,00
-600,00
1 2 3 4 5 6 7 8 9 10 11 12
Month
Zone 1
Zone 2

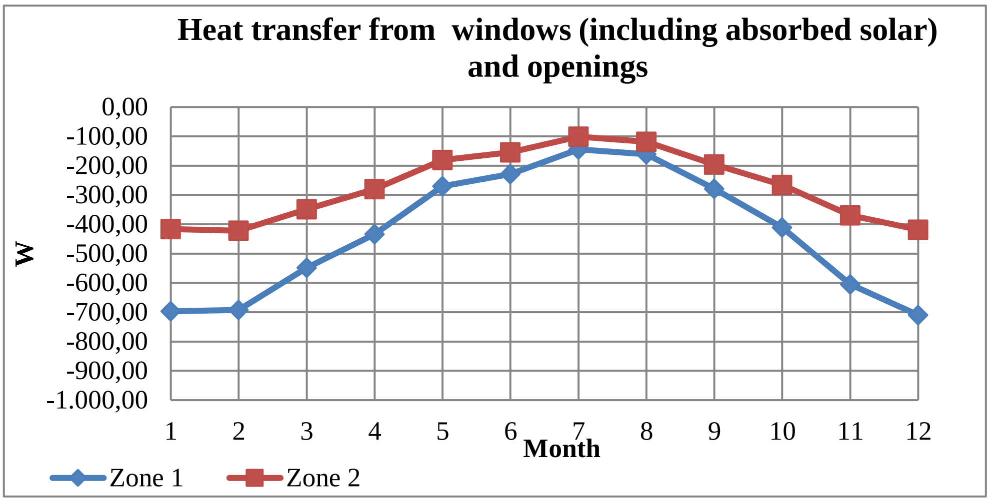
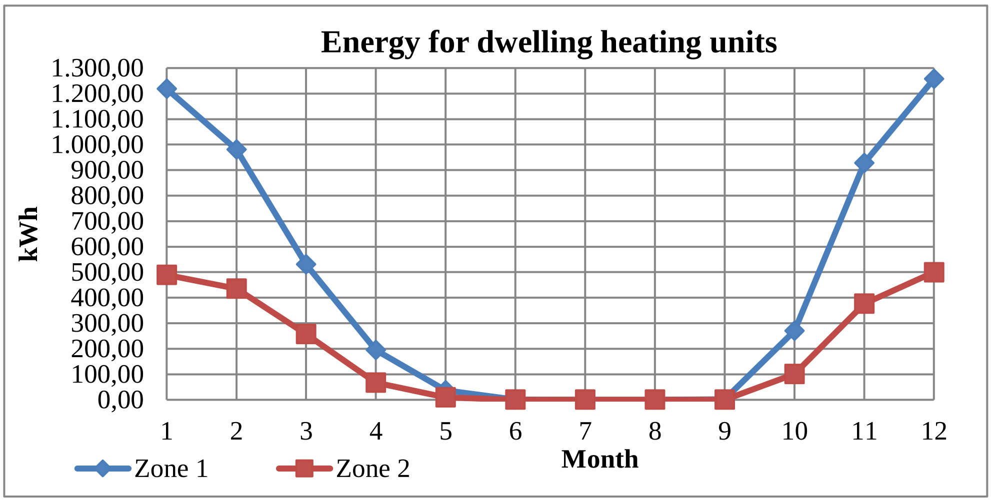


Figure 5.22 Sensibility of heat transfer to floor areas and dwelling orientation

As Fig. 5.23 illustrated, it was verified that energy for space heating contributed actually to compensating the thermal energy loss through envelope, thermal bridges and windows, as well as air flows during the heating period, in which the floor areas played a significant role under the condition of same building materials. The energy gain through windows depended to a certain extent on the window areas and orientation.



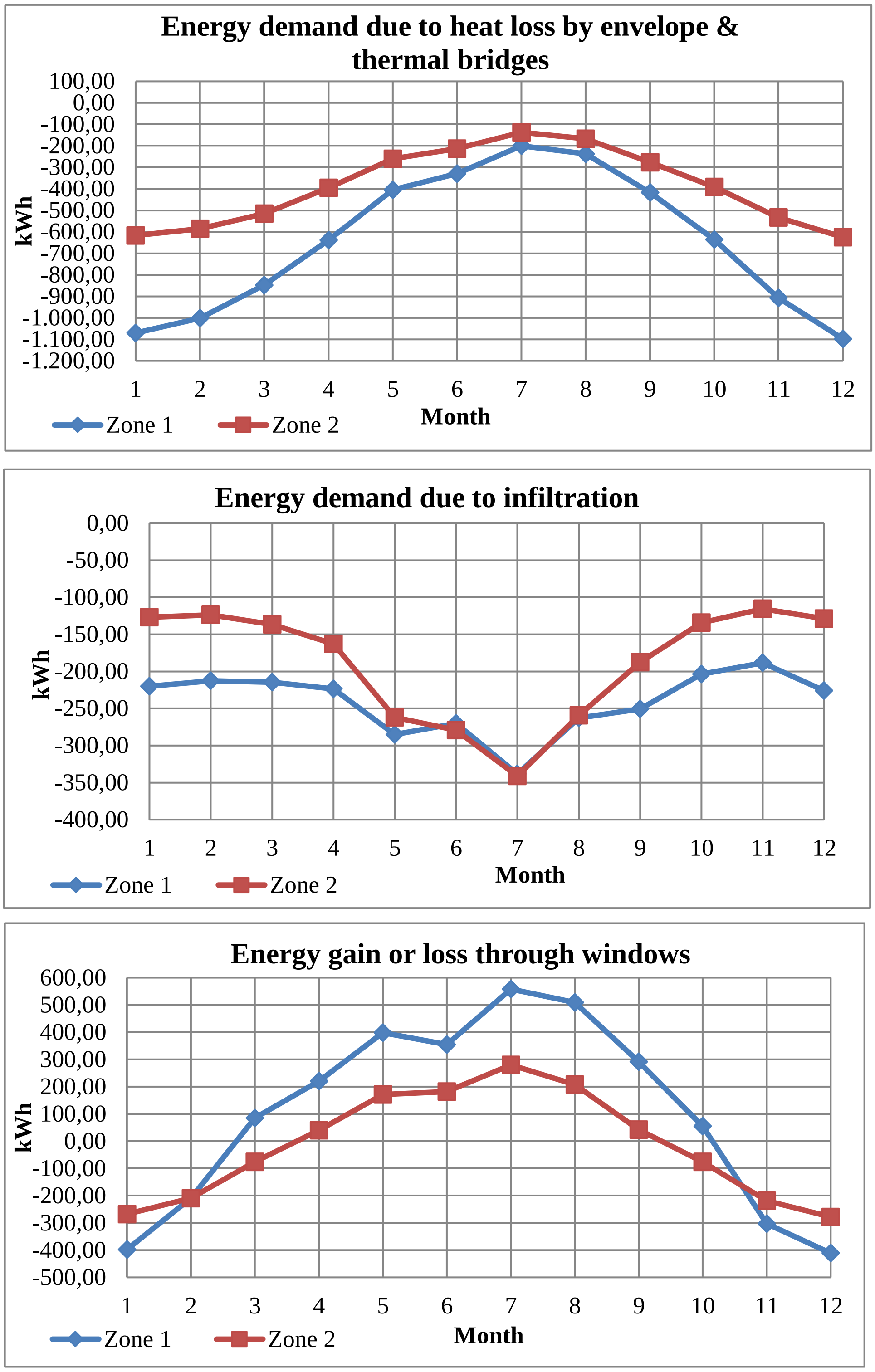


Figure 5.23 Sensibility of energy demand to floor areas and dwelling orientation

Because of same family size with same energy-using schedules, the average amount of CO_2 emissions was same in both dwelling 1 and 2, while the CO_2 concentrations in both dwellings appeared obvious difference owing to different indoor space. Fig. 5.24 showed the comparison of indoor CO_2 concentration in ppm (vol) of dwelling 1 and 2.

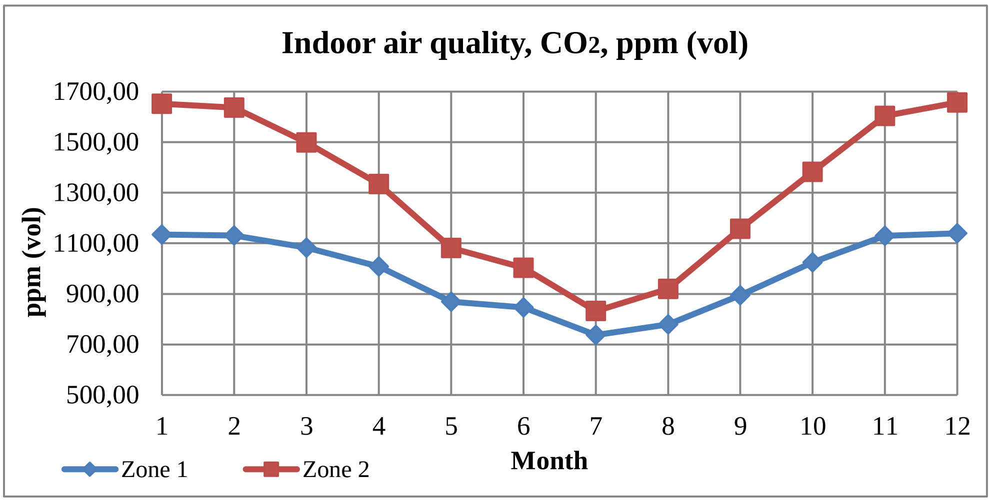
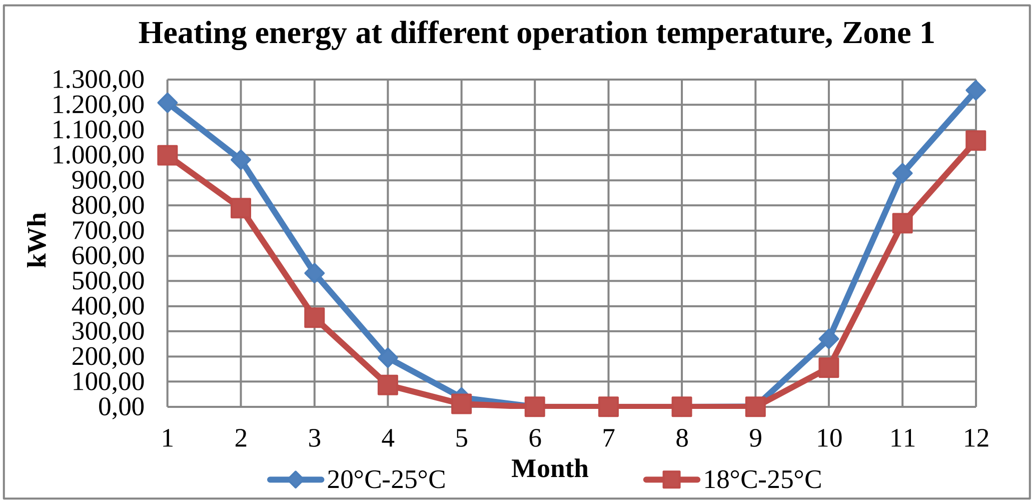


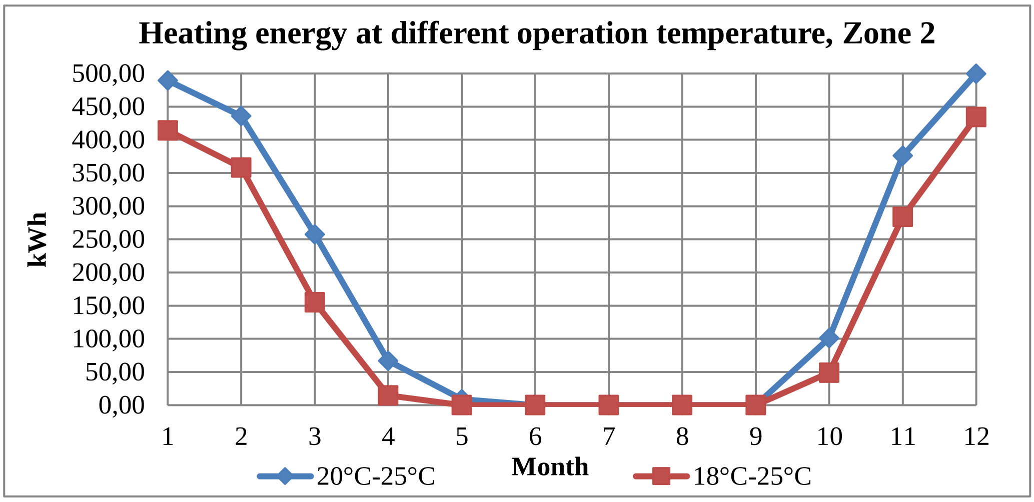
Figure 5.24 Sensibility of indoor CO_2 concentration to floor areas and dwelling orientation

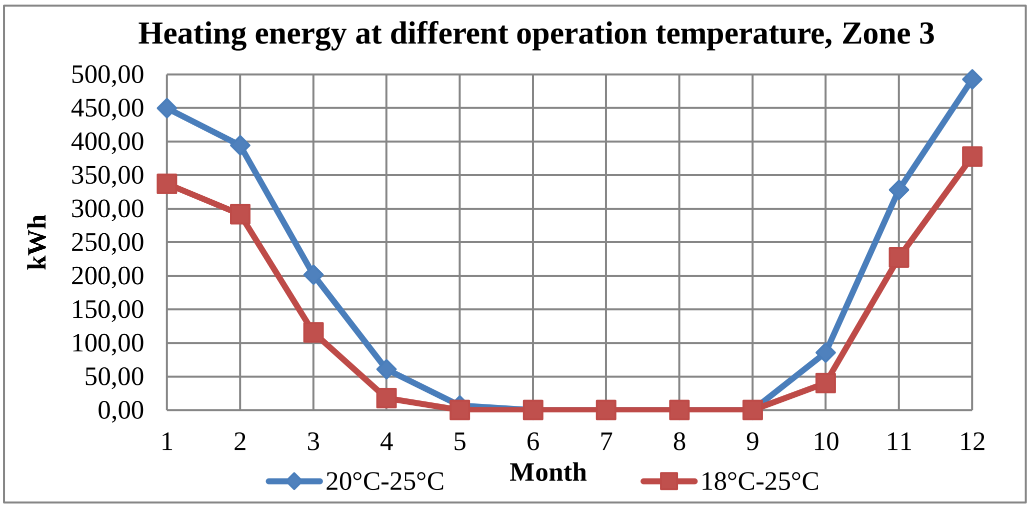
5.5.4 Sensibility to thermostat setting-point

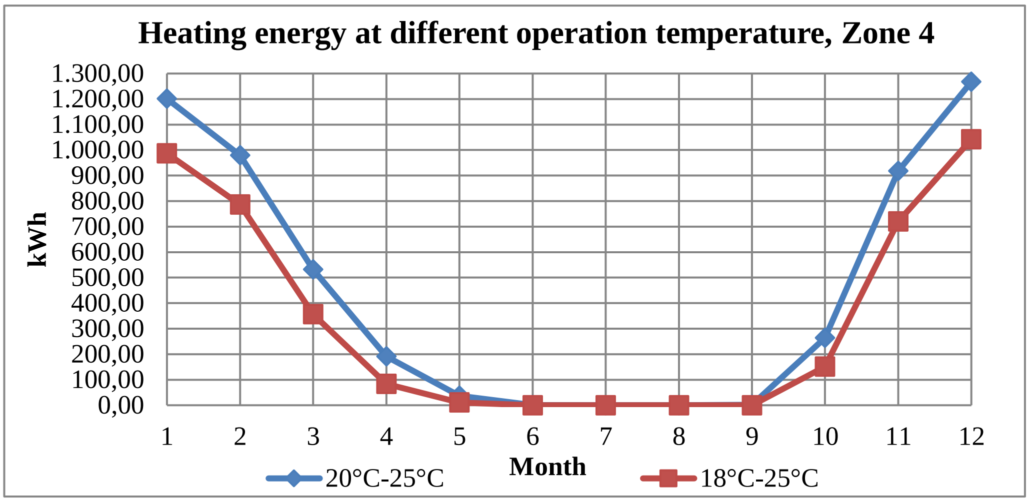
It is worth stressing that the heating set-point plays a very important role in the final heating energy consumption. For example, for a 100 m^2 dwelling the necessary heat supply could be 32% higher with a thermal set-point 21-27°C than with 18-25°C. (Zheng et al. 2018). Last but not least, the impact of floors in multi-storey residential buildings could also lead to a certain difference in heating energy consumption and indoor air quality. In this research, the initial thermal set-point is according to DIN V 18599-10 at 20°C as minimal operation temperature and 25°C as maximal, another thermal set-point range for evaluating its sensibility to heat transfer, energy demand and indoor air quality is 18°C-25°C.

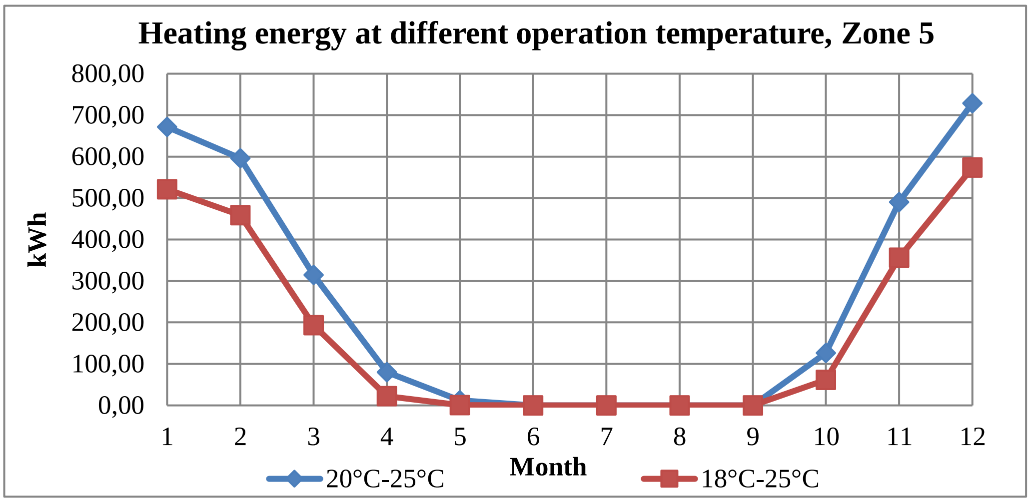
The most vulnerable segment of indoor energy demand should be heating energy consumption, which is influenced by thermal set-point. Fig. 5.25 illustrates the comparison of energy demand for heating in the investigated twelve dwellings at both different operation temperature ranges, i.e. 20°C-25°C and 18°C-25°C.

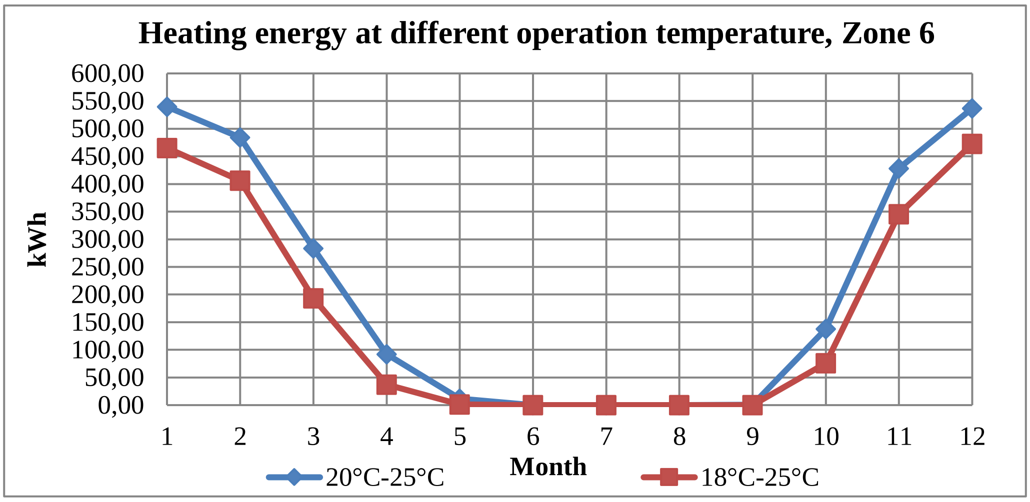

Heating energy at different operation temperature, Zone 1
kWh
1.300,00
1.200,00
1.100,00
1.000,00
900,00
800,00
700,00
600,00
500,00
400,00
300,00
200,00
100,00
0,00
1
2
3
4
5
6
7
8
9
10
11
12
Month
20°C-25°C
18°C-25°C

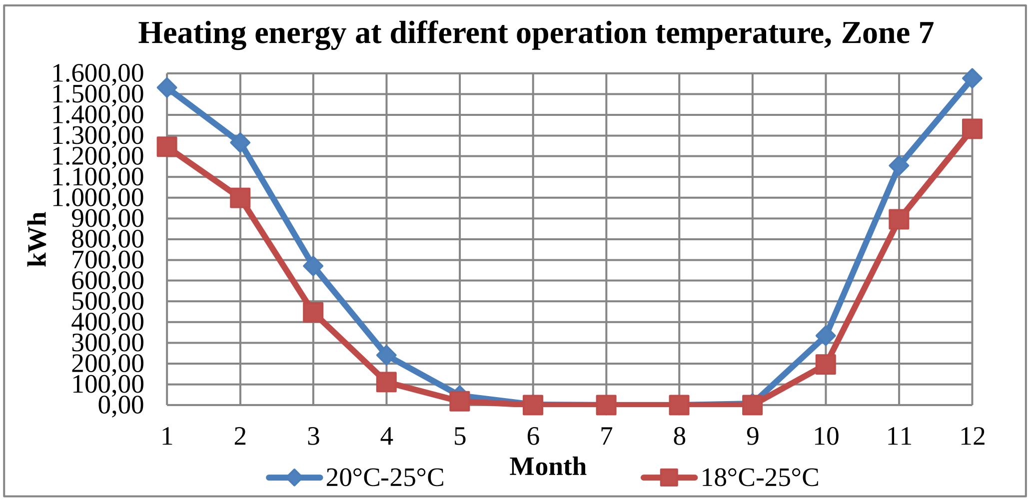

Heating energy at different operation temperature, Zone 2
kWh
500,00
450,00
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
1
2
3
4
5
6
7
8
9
10
11
12
Month
20°C-25°C
18°C-25°C

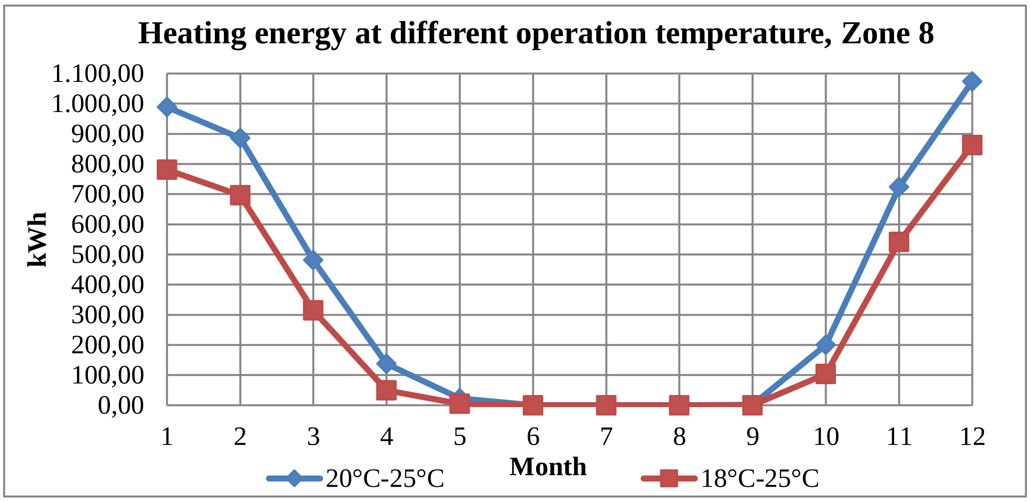

Heating energy at different operation temperature, Zone 3
kWh
500,00
450,00
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
1
2
3
4
5
6
7
8
9
10
11
12
Month
20°C-25°C
18°C-25°C

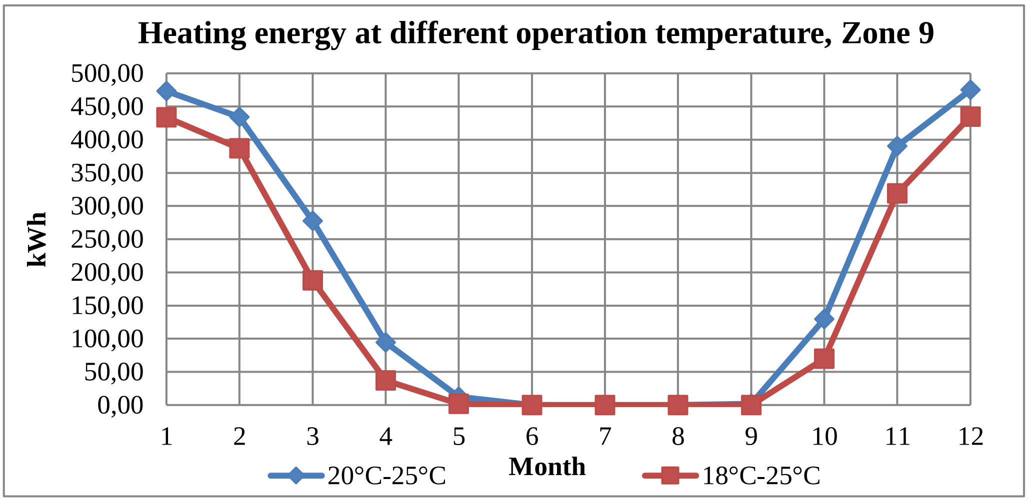

Heating energy at different operation temperature, Zone 4
kWh
1.300,00
1.200,00
1.100,00
1.000,00
900,00
800,00
700,00
600,00
500,00
400,00
300,00
200,00
100,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12
Month
20°C-25°C
18°C-25°C


Heating energy at different operation temperature, Zone 5
kWh
800,00
700,00
600,00
500,00
400,00
300,00
200,00
100,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12
Month
20°C-25°C
18°C-25°C


Heating energy at different operation temperature, Zone 6
kWh
600,00
550,00
500,00
450,00
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12
Month
20°C-25°C
18°C-25°C


Heading energy at different operation temperature, Zone 7
kWh
1.600,00
1.500,00
1.400,00
1.300,00
1.200,00
1.100,00
1.000,00
900,00
800,00
700,00
600,00
500,00
400,00
300,00
200,00
100,00
0,00
1
2
3
4
5
6
7
8
9
10
11
12
Month
20°C-25°C
18°C-25°C


Heading energy at different operation temperature, Zone 8
kWh
1.100,00
1.000,00
900,00
800,00
700,00
600,00
500,00
400,00
300,00
200,00
100,00
0,00
1
2
3
4
5
6
7
8
9
10
11
12
Month
20°C-25°C
18°C-25°C


Heading energy at different operation temperature, Zone 9
kWh
500,00
450,00
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
1
2
3
4
5
6
7
8
9
10
11
12
Month
20°C-25°C
18°C-25°C

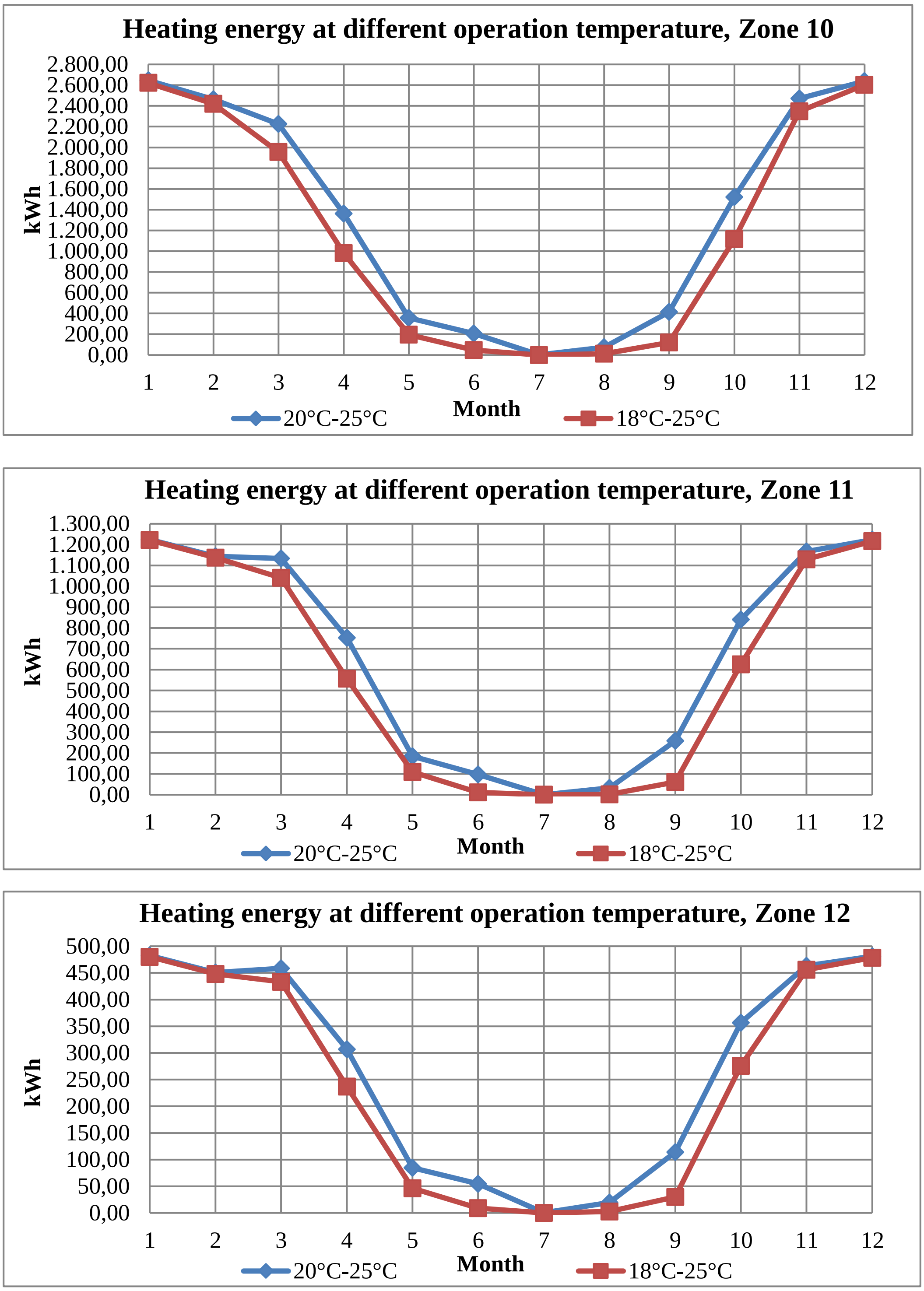
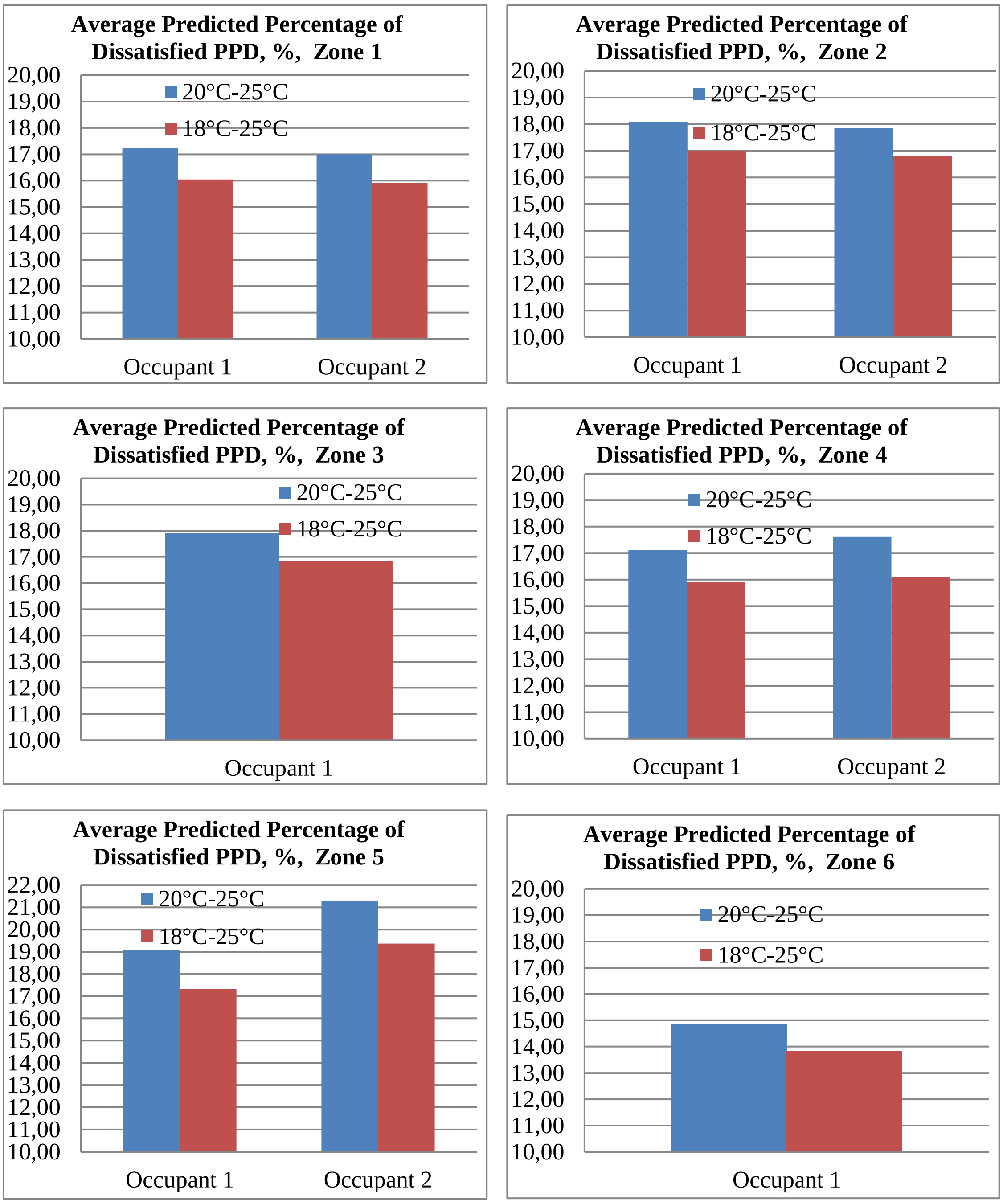


Figure 5.25 Heat energy demand at different thermal operation temperature

It was obvious that energy demand for space heating sinks with lowering thermal operation temperature of heating system, regardless of the physical characters of dwellings (e.g., room orientation and areas) and stochastic factors influencing heating energy consumption (e.g., occupant rate and energy-using schedules). However, it was found that the lower thermal setting point did not lead to uncomfortable thermal experience. Instead, the simulated results of Predicted Percentage of Dissatisfied (PPD, %), which detected whether the living comfort could be scarified by turning down the thermal set-point, discovered a relative higher annual satisfaction rate, i.e. lower PPD value, occurred at lower thermal operation temperature, as Fig. 5.26 depicted.



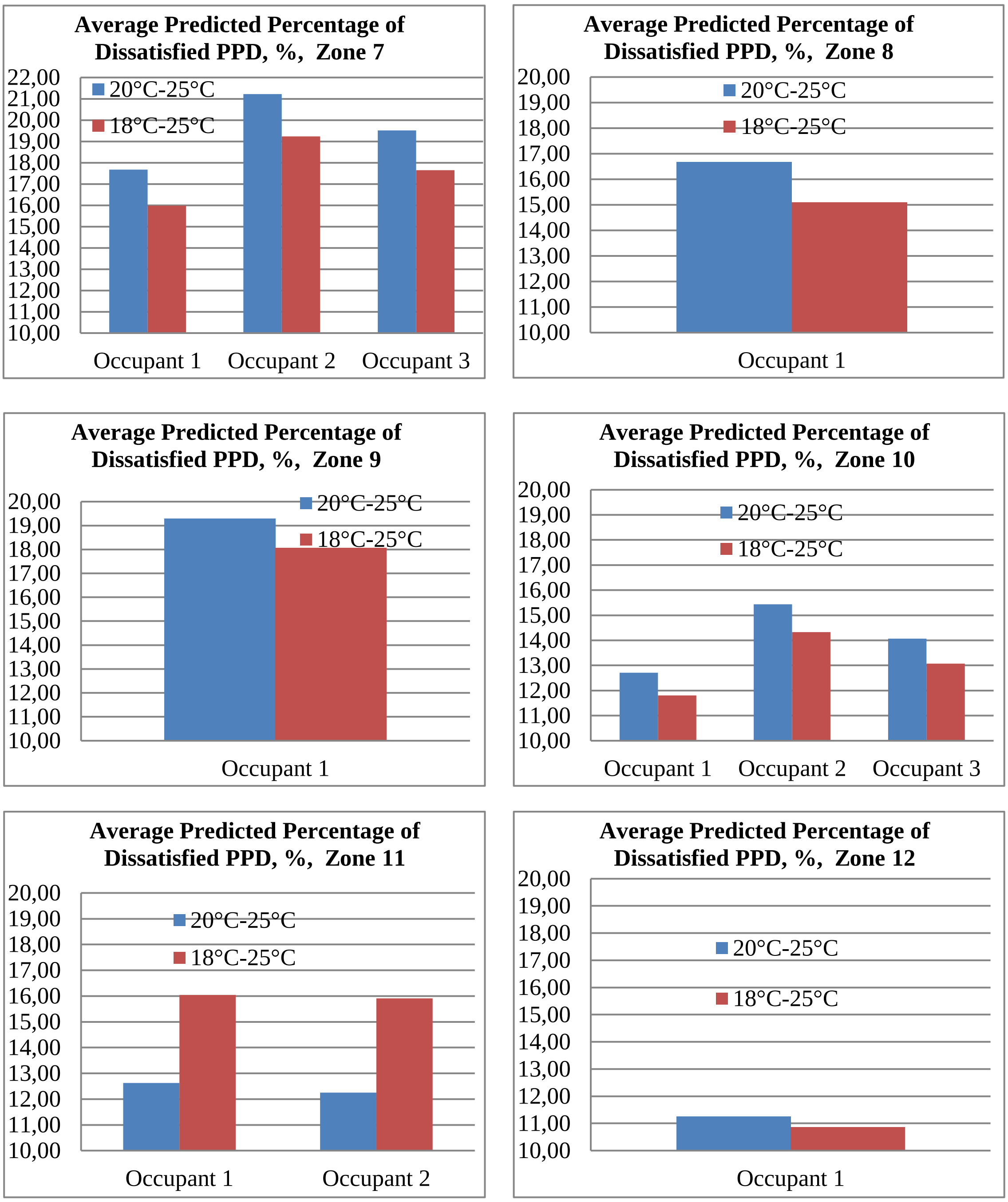


Figure 5.26 Fanger's Comfort Indices - Predicted Percentage of Dissatisfied (%) at different thermal set-point

In this context, it could suggest that a higher indoor thermal comfort and conserving heating energy consumption could be achieved by choosing a rational range of operation temperature of heating system. Meanwhile, an economic and ecologic benefit could be achieved for the stakeholders by this choice.

According to DIN V 18599-1: 2011-12, the primary energy factors for gas as fuel heating source and electricity are 1.1 and 2.8 respectively (Safner 2015). CO_2 emission factor for energy supply in gas for building sector is about 202.0 g/kWh (Hessisches Ministerium der Finanzen 2014), while for domestic electricity consumption is about 601 g/kWh (Umweltbundesamt 2013). Based on statistics of BDEW, the gas price for MFH is 5.24 cent/kWh and 5.78 cent/kWh for EFH. For example, the annual costs accounted about 910 Euro for a family in Wixhausen (Germany) with its max. annual gas consumption 18000 kWh, according to the price offer of energy supplier Entega in Germany[151]. That meant it cost about 4.97 cent/kWh with basis price 10.0 Euro/month. The annual electricity costs for household appliances and lighting accounted, however, about 872.2 Euro for the same family with its max. annual electricity consumption 3600 kWh, supplied by the same energy company Entega, i.e. 26.95 cent/kWh with basis price 12.0 Euro/month[152]. Table 5.13 showed energy costs for gas heating and CO_2 emission during the whole heating period under different thermal set-point.

Table 5.13 Impact of thermal set-point on heating energy demand and the resulted CO_2 emissions

Building			
		20°C – 25°C	18°C – 25°C
Heating supply/a	kWh	66133.2	54083.4
Gas price	Ct/kWh	4.97	4.97
Basis price	Euro/kWh	10	10
Heating energy costs	Euro	3406.82	2807.94
CO_2 emission factor	g/kWh	202	202
Annual CO_2 emissions	kg	13358.9	10924.8

The fuel heating energy costs could be reduced 17.6%, if the thermal set-point could be regulated from 20°C-25°C to 18°C-25°C, and therefore the resulted CO_2 could achieve an 18.2% reduction. Comparing with heating energy, the electricity demand for household appliances and lighting would be out of influence of thermal set-point, however, if building is supplied with electricity for cooling, it might be affected at a little extent, because which is basically depending on the weather condition and occupant behaviour, such as preferring cooling temperature in summer.

151 https://www.entega.de/preis-vergleich/gaspreise/tarifdetails/#tariffDetails

152 https://www.entega.de/oekostrom/tarifdetails/#tariffDetails

5.6 Barriers and limits

The most barriers for investigating energy demand and consuming attributes in this research work occurred during data collection, which referred to, in particular, the energy-related occupant behaviours, i.e. occupancy, activity on heating and other household appliances, and the acceptability of energy-saving measures. During the process of occupant recruitment before data collection, some of occupants had still doubt on the research project and the expected energy saving potential, due to on one hand privacy, on the other hand little interest on it. It had to perform this work in different ways. For example, motivation-focused ways for occupants who did not consider new energy-saving measures as profitable or beneficial, finance-related ways for low-income occupants who could not afford more expenditure for energy-efficient products and services, and education-related ways for people who had comprehension difficulties on research work because of immigration background, or most were not familiar with information and communication technologies (ICT). In addition, some information from occupants by questionnaires was proved untrue at a certain extent in the subsequent process, which meant there was some cognitive bias when occupants evaluated their energy-using behaviour and energy-saving awareness by themselves.

Due to strict privacy protection in Germany, it was hard to collect data on the daily routines of occupants at home through monitoring with sensors. This was not a technical barrier anymore and therefore needed an effective support from the government with relevant regulation.

Lack of complete and real data for simulation might lead to incomplete results for further analysis. IDA ICE version 4.7, as a building simulation tool, takes the intervention of occupants during an energy simulation process into account. Some research of OB impacts on home energy consumption have been simulated by IDA ICE a few years ago (Andersen et al. 2011, Fabi et al. 2012, D’Oca et al. 2014), according to OB probabilities developed in logic regression, which however was based on high volume of OB data by observing and measuring.

5.7 Conclusion

A combined comfort analysis and energy demand simulation are pursued taking into account of occupants behaviour and awareness, as well as the benefits of the included stakeholders, which brings the value to gain holistic understanding and assessment of energy efficiency optimization in residential areas. Computerization of housing energy consumption is performed yearly, monthly, daily and hourly, even peak value that aims to assess the impact of the investigated parameters and their interaction with occupants. Each influence factor works as a variable for the simulation to analyse their interaction among each other and finally to find out the best combination to optimize energy efficiency in residential buildings, for example,

- To investigate the implication of climate change for energy demand as a function of region-specific climate variables, energy equipment and use profiles.

- Or simulation models can illustrate the impact of temperature change on final energy use by different fuel sources, house types and occupancy status etc., the counteraction too.

- User behaviour as subjective influencing factor varies with other objective influencing factors, such as energy price, socio-economic background of users, and energy politics etc.

- The share of renewable energy in final energy consumption or combined heat and power generation.

As before mentioned, energy efficiency of residential buildings is affected by different potential factors. It is hard to identify the most influencing factors without a comprehensive simulation combination. Investigation of residential energy efficiency pursues not only to reduce the final energy consumption and energy costs in quantity, but also to improve the living comfort with technically feasible, economically attractive and long-term ways. Therefore, in-depth analyses from different perspectives are needed for future studies, for example, cost-benefit-analysis (CBA), from economical perspective is assessing the profitable possibilities of an investigation, which are performed by all stakeholders and meanwhile could benefit all of them. Furthermore, cost-comfort-analysis (CCA), which emphasizes the production of investigated technologies and services rather than the available return in money, aims to assess whether the indoor living quality would be improved with the available technological and economical investment. The advantage of cost-comfort-analysis in energy efficiency is to avoid the impact of fluctuation of future energy prices, which is the major source of uncertainty in the appraisal of energy efficiency investments. From the perspective of real estate, CCA pays a certain attention to the occupants satisfaction, which could be a direct link between high living satisfaction and higher stock prices, value of shareholders, and higher credit quality (Leuthauser and Weaver 2010).

CBA and CCA could be the important components of an overall portfolio of residential energy efficiency, in case of association with the technical aspects. Therefore, a demand-support-interactive management would be established for benefiting from an effective investment in residential energy efficiency.

6 Discussion

6.1 Driving forces

The acceptable principle depends on the individual identifications of indoor environmental comfort, which guide occupant behaviour to the decisive degree. Corgnati et al. (2011) indicated in their study that the comfort requirements by occupants regarding to thermal conditions and indoor environmental quality represents a high expense of energy. As the simulation in chapter 5 showed, the main affecting factor on heating energy consumption is heating set-point. Meanwhile, other factors should not be neglected like manual ventilation action that depends on the one hand upon the living habits, on the other hand upon the outdoor environmental conditions (e.g., temperature, humidity, air quality). Regarding household electricity consumption, it makes up a small proportion of residential energy consumption compared with energy for room heating and depends considerably on the power of domestic electric appliances.

6.1.1 Heating set-point

Except for the performance of heating system, the behavioural patterns regarding thermal radiator valves reflects the temperature-sensibility of occupants and energy saving awareness to a certain extent. According to survey during the research work, overheating often occurred in some households. Misperception or neglecting or incorrect operation of thermal set-point adjustment would be the main reason when occupants interact with heating control. Most calculation for energy consumption is always assumed a constant thermal set-point during the whole simulation process, which would result in inaccurate or wrong outcomes, because in fact the set-point temperature varies at all times under the influence of occupant behaviour and perception. Therefore, some simulated energy performance of building is inadequate for buildings having close interactions with occupants (Hoes et al. 2009), in particular for residential buildings where occupants behave more stochastically and diversely.

The heating setting behaviour of occupants is affected by many factors, as before discussed. The outdoor temperature, solar radiation and climate (rainy, windy), as well as clothing adjustment affect the behaviour of occupants by heating setting and therefore change the indoor temperature, in turn, which influences this heating setting behaviour too and even window opening behaviour of occupants. It is a random, iterative, and highly individual process until achieving a comfortable indoor temperature.

6.1.2 Window opening/closing behaviour

Manuel ventilation through opening/closing windows depends on indoor air temperature and air quality, as well as on the living habits of occupants, e.g., some occupants are used to opening windows at the same time and for a same while every day. In this research, it was assumed that occupants would open windows if the indoor temperature exceeds 28°C. During the unoccupied period, the windows are assumed to be always closed.

However, the temperature-sensibility of occupants is very individual and affected by they own activities (different met values) and clothing adjustment to a certain degree. It is worth noting that the perception of indoor air quality (e.g., odours, mould) drives also behaviour by windows, therefore it could be considered that the living discomfort is one of main drivers for window opening, even it might result in too lower indoor temperature for a short time, in other words, it could be a trade-off behaviour. Actually it was proved in my survey by occupants in German social housings, the action of window opening/closing is more related to optimize indoor air quality rather than thermal comfort.

6.1.3 Independent conditions

Except for the behaviour by heating regulation and window, there are some other factors that affect the domestic energy consumption. For example,

- the building/dwelling orientation has an obvious impact on indoor temperature owing to direct solar radiation. It was reported by occupants in a passive building that the temperature of their children’s room with west exposure is lower than in other rooms, according to survey in the project,

- Ownership status of dwelling plays also a very important role in energy-related behaviour. Self-owned residents are willing to accept energy-efficient products and service, if a necessary cost is affordable and recoverable in an acceptable payback period (e.g., reduction of energy consumption and expenditure, increase of indoor living environment),

- Energy price, in particular electricity pricing. Mirakhoril and Dong (2017) stated in their research that electricity dynamic pricing for residential buildings would be a critical step toward involving numerous consumers of electricity in an interactive electricity market, where consumers should negotiate for the price of electricity or services they received.

6.2 Limits to simulation

6.2.1 Validity of data sources

One of the primary limitations of this study is that actual data was not comprehensive enough for analysing and modelling owing to strict data protection and privacy in Germany, in particular for achieving the data on occupancy and indoor energy-using activities with a necessary accuracy and degree of detail. For occupants with low-income and energy conservation awareness in social housing buildings, comprehensive and long-term introduction have to be conducted to gain the trust of occupants and thus to attract occupants into and support the investigation. It is not a technical barrier anymore, but an effective support from government with relevant regulation and laws is strongly suggested and an appropriate reward mechanism would be complementary to productivity.

Differences in profiles of thermal operation temperature and occupant behaviours explain most of discrepancy in energy consumption and indoor environmental quality, which have been proved by many studies (Seligman et al. 1977/78, Hackett et al. 1991, Lutzenhiser and Gossard 2000, Andersen 2009). Occupant behaviours are mostly haphazard and transient, and the intention of their behaviours cannot be explained in a single causal relationship but rather an intricate process with multiple causalities (Lee 2013). However, in many simulation modelling the thermal operation temperature is assumed constant, and the occupancy and schedules of occupant behaviours are assumed very regular to a certain extent, such as the same time of each day for window-opening. However, this is actually questionable and impractical.

6.2.2 Functionality of analytical methods

This doctoral research was inspired by the considerable difference of energy consumption among households with the same technical conditions, which led to account for occupant interaction with the control of indoor environmental quality. The method was predominantly invested in data collection and information acknowledgement by the ways of survey with questionnaires and calculation of energy consumption. Though questionnaires has been always considered as a real-time data gathering method, as Bijker et al (1987) mentioned in their research that information gathering with questionnaires was one of the promising routes for artificial intelligence, because it is not only concerning about the behaviour itself, but also about the environment in which it takes place. However, during the surveying for the real situation, it was found that cognitive bias and limited understanding and interest were the major impediments to the consistency and reliability of collected information about energy-related behaviours and awareness.

With regard to simulation process, as a matter of fact, it was conducted based on many hypothesis owing to the uncertainties of occupant behaviours, which therefore aggravated the uncertainty of simulation results. For example, the thermal set-point as one of the critical variants for simulating energy consumption and indoor thermal comfort changes at all times and resulted in effects on occupant behaviours in turn. However, many simulation models take it as a dependent variable in the linear regression, which means it is only influenced by some environmental stimulus, such outdoor temperature, or occupancy status, so-called “occupied-on and unoccupied-off”, but less by some subjective choices or preferences. The same limitation occurs during simulating interaction with windows. Increasing models are designed with adaptive and adjustable variants. Dear and Brager (1998) suggested the adaptive models of thermal comfort in their research, which highlights the “adaptive” character of thermal perception of occupants instead of “static” character. The “static” model views the person as a passive recipient of thermal stimuli, which is actually inadequate to describe the thermal perception of occupants in the real situation. In contrast, the “adaptive” model recognizes all interaction of occupants with thermal perception, which refer to demographics (gender, age, social and economic status), context (climate, building design, energy equipment) and cognition (attitude, awareness and expectations) (Mclntyre 1982, Baker and Standeven 1994, Oseland 1994, Griffiths et al. 1988), which is though very complicated more alike the real situation.

As a simulation tool in this research work, IDA ICE performed a heat/energy balance on each zone of a building in order to simulate thermal comfort, energy consumption and indoor air quality. Although it is easy to use and any further extension could be added into initial models, it might have a long run time depending on the complexity of the model structure (Schwab and Simonson 2004). In addition, referring to thermal set-point it could not simulate different zones of a building with individual thermal set-point at the same model, which restricted the investigation of behavioural diversity in real cases.

In summary, building energy efficiency cannot be achieved without addressing the human factor, which is one of the key factors for design optimization, energy diagnosis and performance evaluation, and building energy simulation (Yan et al. 2017). Occupant behaviour (OB) is not in a mode of „*if-then*“ (Jia et al. 2017), especially for residential buildings where occupant behaviour has higher randomness and diversity. Occupant behaviour modelling is an effective way to improve the prediction of building energy performance, but various researches show that it needs to be improved constantly. Meanwhile, an effective instrument for data collection must be established or optimized to provide complete, authentic information for effective OB simulation.

7 Conclusion and perspective

Energy conservation in buildings, especially in residential buildings, is understood as reduced energy consumption through simple and user-friendly ways with lower additional monetary investment. The goal of energy conservation research is to establish a system-oriented optimization concept, which shall emphasize the influence of interaction of humans. Since the expected effects of efficient energy service input depend on and are affected by the end-users, also building occupants, therefore it is crucial to take the occupant manipulation of building energy system into account. The aim of this system-oriented optimization concept with focus on human interaction is on the one hand to avoid rebound effect in building energy efficiency, on the other hand to improve the accuracy of foresight during the design phase of building energy system. Ackoff and Gharajedaghi (1996) indicated in their research that a building should be considered as a dynamic and functional whole that consists of a series of subsystems, which could be understood that subjective systems (human beings) interact closely with objective systems (technologies, mechanisms), and are affected by the social systems.

Social housing group as a specific object of this Ph.D. research has its uniqueness with regard to energy conservation. Occupants in the social housings are entitled to a certain of level of living quality and energy saving services, which is part of social equity and contribution to economic and environmental improvement. However, it doesn’t means that those occupants act in an energy efficient manner or grasp the knowledges and experiences on household energy efficiency, nor they can afford high-efficient energy appliances and services. It is therefore proposed that more efforts are given on improving the energy-saving awareness through education, dissemination and technological support, as well as supervise and promotion by the relevant standards, which helps social housing residents comprehensively understand the benefits of building energy efficiency investment by other stakeholders. Comparing with other resident groups, social housing residents need be encouraged and persuaded to act more resource-conserving and environmentally friendly instead of merely proving the energy efficient technologies. This would be a repeatedly process with follow-up visits rather than a one-off visit to ensure that occupants can benefit from energy-efficient technologies through acting more energy-saving consciously.

This dissertation underscored the importance of occupant behaviour and awareness towards household energy conservation as one of the key elements in investment of residential building energy efficiency. Energy-related occupant behaviours for controlling indoor environmental quality are quite complex and diverse, which is underestimated in the process of building designing by architect and engineering. In this research work, five main aspects were discussed for eliciting the diversity and randomness of occupant behaviours, namely, urban economic condition and situation, energy performance attributes of residential building, social demographic characters of stakeholders, access and availability of energy-related technologies, and the relevant politics and regulation, which aimed to find out all the potential factors that influence occupant behaviours regarding to home energy conservation as far as possible. With regard to the effects on energy consumption and indoor living comfort, occupant behaviours were investigated mainly by means of questionnaire survey for data collection, simulation for predicting and analyzing the variability of effects.

From the investigation of the research work, it could be concluded that:

- Obvious diversity of energy-related behaviours and awareness and expectation towards energy conservation among investigated households. The energy conservation awareness and ability is relatively lower in social housing residents than other residential groups,

- Behaviours on heating regulation were significantly affected and stimulated by outdoor temperature and individual perception of indoor temperature,

- Thermostat setting-point as one of key variants in simulation was confirmed as an advantageous instrument to guaranteeing indoor thermal comfort and heating energy conservation.

Occupant interaction with building energy systems is a double-edged sword, which means, higher possibility and capacity of occupant access to energy systems may bring higher living satisfaction than those who are exposed to environment of which they have no control (Andersen 2009). However, it could create added costs and energy consumption. The study in this dissertation foments many questions in need of further research, such as,

- **how to motivate the behavioural change of occupants?** Behavioural change is a highly complex and time-consuming task but a most effective way for saving domestic energy in a long run. This study has indicated that energy-saving awareness varies with households with different income, therefore it is necessary to invest different motivation strategies in different targeted income group, and with different expectation of energy conservation,

- **What are the main parameters affecting residential energy consumption?** Residential energy consuming is highly random process, which is time-dependent (e.g., season-dependent, hour-dependent), location-dependent, technics-dependent, socio-dependent and costs-dependent. This issue should be discussed with consideration of real situation and be solved both taking immediate difficulties and long-term potential crisis,

- **How to emphasize the environmental impact resulted from residential energy**

consumption to occupants? Spontaneous and voluntary energy-saving behaviours are always the most lasting and effective, as well pursed by society. However, the intention or potential motivation is mostly for reason of saving money rather than environmental protection. This is a topic that needs more engagement from different responsible parties, e.g., indoctrination of information, feedback and exchange, enforced by regulation, supervised by community or public etc.

In addition, different simulation models could be developed for complex behaviours matrix, for example, except for the popular used agent-based models, the „bottom-up models“(Grandjean et al. 2012, Shimoda et al. 2010) is equipped with much detail energy-related data and capable to address the effect of occupant behaviours on energy consumption, which are superior in handling technological advancement to reduce energy consumption and has comparative advantage than „top-down models“ (Grandjean et al. 2012) relying on historical data instead of in details, so that it is not easy or through this model to identify key improvement measures or areas for reducing energy consumption.

The importance of residential energy efficiency has been confirmed by many studies. Improving energy efficiency in residential building, in particular social housing for low-income households, contributes directly not only to renter or homeowner, but also to the local community and region from the perspective of energy and resource, environmental and economic benefits, meanwhile, has an indirect benefit of reducing the reliance of occupants on energy assistance programs provided by communities and government. Therefore, an integrated investment comprising the efforts from all relevant stakeholders is pursued to ensure energy efficiency during the whole life cycle of residential building in a multidimensional manner.

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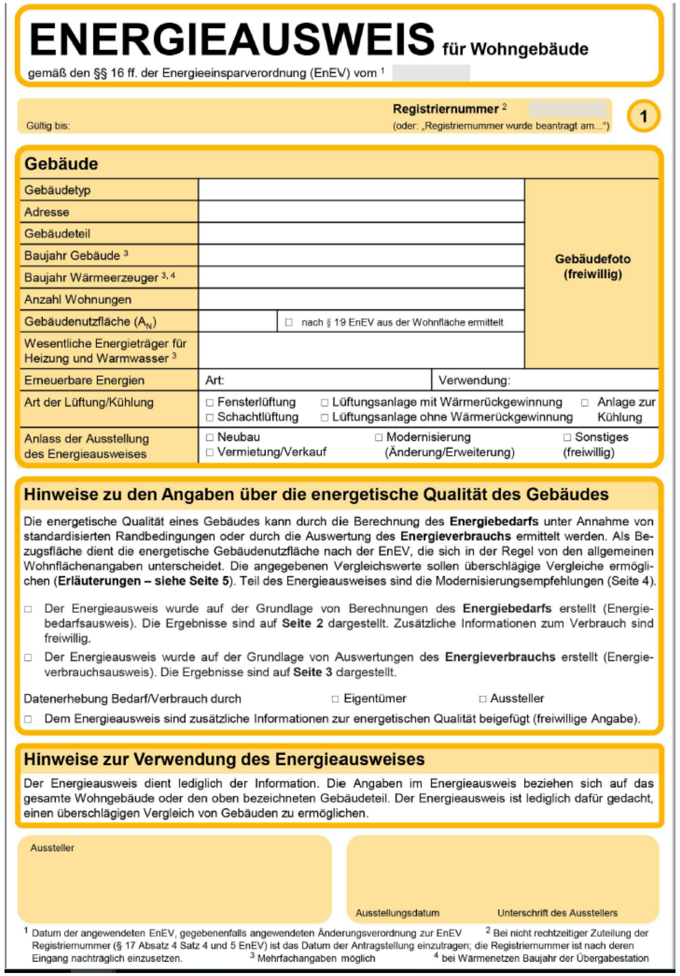
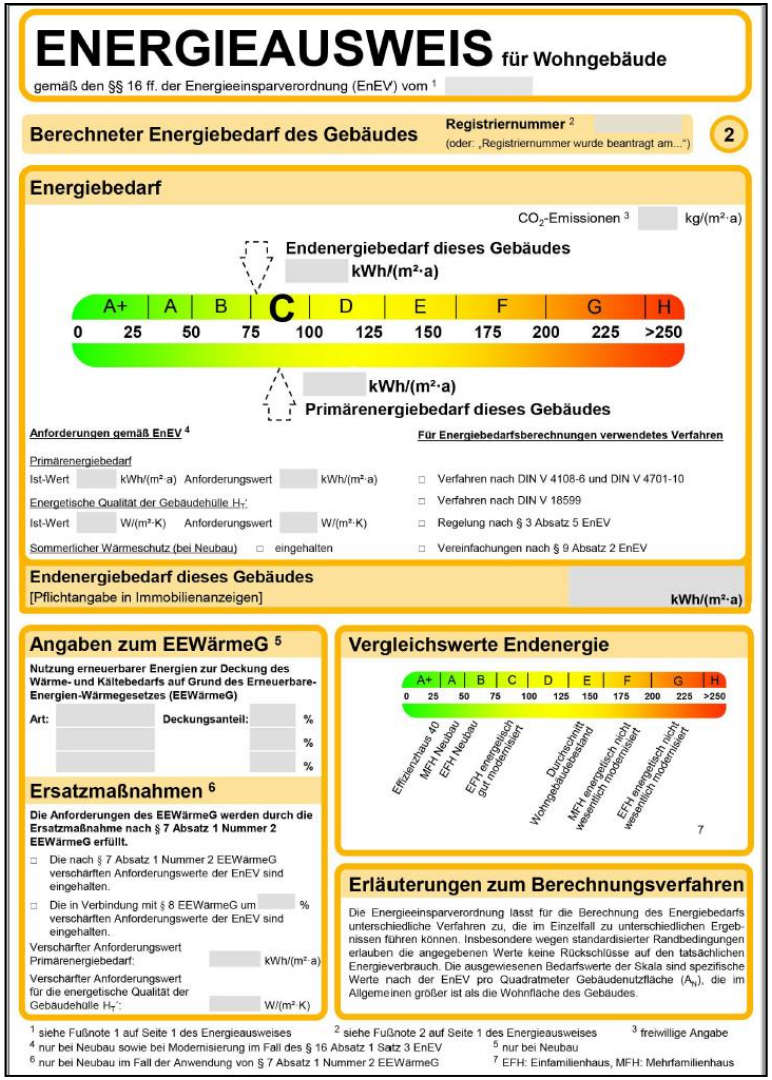
Appendix 1 German EPCs for residential building

<table>
<tr><th>EPCs</th><th>Form</th><th>Content of sheet</th></tr>
<tr>
<td>Sheet 1</td>
<td>
ENERGIEAUSWEIS für Wohngebäude
gemäß den §§ 16 ff. der Energieeinsparverordnung (EnEV) vom [1]
Gültig bis: Registriernummer [2] (oder: „Registriernummer wurde beantragt am...“) 1
Gebäude
Gebäudetyp
Adresse
Gebäudeteil
Baujahr Gebäude [3]
Baujahr Wärmeerzeuger [3, 4]
Anzahl Wohnungen
Gebäudenutzfläche (A_N) ☐ nach § 19 EnEV aus der Wohnfläche ermittelt
Wesentliche Energieträger für Heizung und Warmwasser [3]
Gebäudefoto (freiwillig)
Erneuerbare Energien Art: Verwendung:
Art der Lüftung/Kühlung ☐ Fensterlüftung ☐ Schachtlüftung ☐ Lüftungsanlage mit Wärmerückgewinnung ☐ Lüftungsanlage ohne Wärmerückgewinnung ☐ Anlage zur Kühlung
Anlass der Ausstellung des Energieausweises ☐ Neubau ☐ Vermietung/Verkauf ☐ Modernisierung (Änderung/Erweiterung) ☐ Sonstiges (freiwillig)
Hinweise zu den Angaben über die energetische Qualität des Gebäudes
Die energetische Qualität eines Gebäudes kann durch die Berechnung des Energiebedarfs unter Annahme von standardisierten Randbedingungen oder durch die Auswertung des Energieverbrauchs ermittelt werden. Als Bezugsfläche dient die energetische Gebäudenutzfläche nach der EnEV, die sich in der Regel von den allgemeinen Wohnflächenangaben unterscheidet. Die angegebenen Vergleichswerte sollen überschlägige Vergleiche ermöglichen (Erläuterungen – siehe Seite 5). Teil des Energieausweises sind die Modernisierungsempfehlungen (Seite 4).
☐ Der Energieausweis wurde auf der Grundlage von Berechnungen des Energiebedarfs erstellt (Energiebedarfsausweis). Die Ergebnisse sind auf Seite 2 dargestellt. Zusätzliche Informationen zum Verbrauch sind freiwillig.
☐ Der Energieausweis wurde auf der Grundlage von Auswertungen des Energieverbrauchs erstellt (Energieverbrauchsausweis). Die Ergebnisse sind auf Seite 3 dargestellt.
Datenerhebung Bedarf/Verbrauch durch ☐ Eigentümer ☐ Aussteller
☐ Dem Energieausweis sind zusätzliche Informationen zur energetischen Qualität beigefügt (freiwillige Angabe).
Hinweise zur Verwendung des Energieausweises
Der Energieausweis dient lediglich der Information. Die Angaben im Energieausweis beziehen sich auf das gesamte Wohngebäude oder den oben bezeichneten Gebäudeteil. Der Energieausweis ist lediglich dafür gedacht, einen überschlägigen Vergleich von Gebäuden zu ermöglichen.
Aussteller
Ausstellungsdatum Unterschrift des Ausstellers
[1] Datum der angewendeten EnEV, gegebenenfalls angewendeten Änderungsverordnung zur EnEV [2] Bei nicht rechtzeitiger Zuteilung der Registriernummer (§ 17 Absatz 4 Satz 4 und 5 EnEV) ist das Datum der Antragstellung einzutragen; die Registriernummer ist nach deren Eingang nachträglich einzusetzen. [3] Mehrfachangaben möglich [4] bei Wärmenetzen Baujahr der Übergabestation</td>
<td>Necessary building information:
• building type, building foto (by choice)
• building address
• building year,
• year of energy-related equipment,
• number of apartments in the building,
• effective energy reference surface area A_N,
- $A_N = V_e \cdot 0{,}32$/m, where V_e = heated building volume enclosed by the heat transferring surrounding area A, which is determined according to EnEV 2009, Annex 1 No. 1.3.1.
- $A_N = 1{,}35 \cdot A_{Wohnen}$, for building type which has up to two dwellings with heated basement.
- $A_N = 1{,}20 \cdot A_{Wohnen}$, for all other building types
• building ventilation information,
• the reasons of the exhibition of EPCs,
• brief explanation of building quality
• Instruction for using EPCs
• EPCs issuer</td>
</tr>
</table>

Sheet 2		

ENERGIEAUSWEIS für Wohngebäude

gemäß den §§ 16 ff. der Energieeinsparverordnung (EnEV) vom [1]

Berechneter Energiebedarf des Gebäudes

Registriernummer [2]
(oder: „Registriernummer wurde beantragt am...")

2

Energiebedarf

CO_2-Emissionen [3] kg/(m²·a)

Endenergiebedarf dieses Gebäudes
kWh/(m²·a)

A+ | A | B | C | D | E | F | G | H
0 25 50 75 100 125 150 175 200 225 >250

kWh/(m²·a)
Primärenergiebedarf dieses Gebäudes

Anforderungen gemäß EnEV [4]

Primärenergiebedarf
Ist-Wert kWh/(m²·a) Anforderungswert kWh/(m²·a)
Energetische Qualität der Gebäudehülle H_T':
Ist-Wert W/(m²·K) Anforderungswert W/(m²·K)
Sommerlicher Wärmeschutz (bei Neubau) □ eingehalten

Für Energiebedarfsberechnungen verwendetes Verfahren

- □ Verfahren nach DIN V 4108-6 und DIN V 4701-10
- □ Verfahren nach DIN V 18599
- □ Regelung nach § 3 Absatz 5 EnEV
- □ Vereinfachungen nach § 9 Absatz 2 EnEV

Endenergiebedarf dieses Gebäudes
[Pflichtangabe in Immobilienanzeigen] kWh/(m²·a)

Angaben zum EEWärmeG [5]

Nutzung erneuerbarer Energien zur Deckung des Wärme- und Kältebedarfs auf Grund des Erneuerbare-Energien-Wärmegesetzes (EEWärmeG)

Art: **Deckungsanteil:** %
%
%

Ersatzmaßnahmen [6]

Die Anforderungen des EEWärmeG werden durch die Ersatzmaßnahme nach § 7 Absatz 1 Nummer 2 EEWärmeG erfüllt.

- □ Die nach § 7 Absatz 1 Nummer 2 EEWärmeG verschärften Anforderungswerte der EnEV sind eingehalten.
- □ Die in Verbindung mit § 8 EEWärmeG um % verschärften Anforderungswerte der EnEV sind eingehalten.

Verschärfter Anforderungswert Primärenergiebedarf: kWh/(m²·a)
Verschärfter Anforderungswert für die energetische Qualität der Gebäudehülle H_T': W/(m²·K)

Vergleichswerte Endenergie

A+ | A | B | C | D | E | F | G | H
0 25 50 75 100 125 150 175 200 225 >250

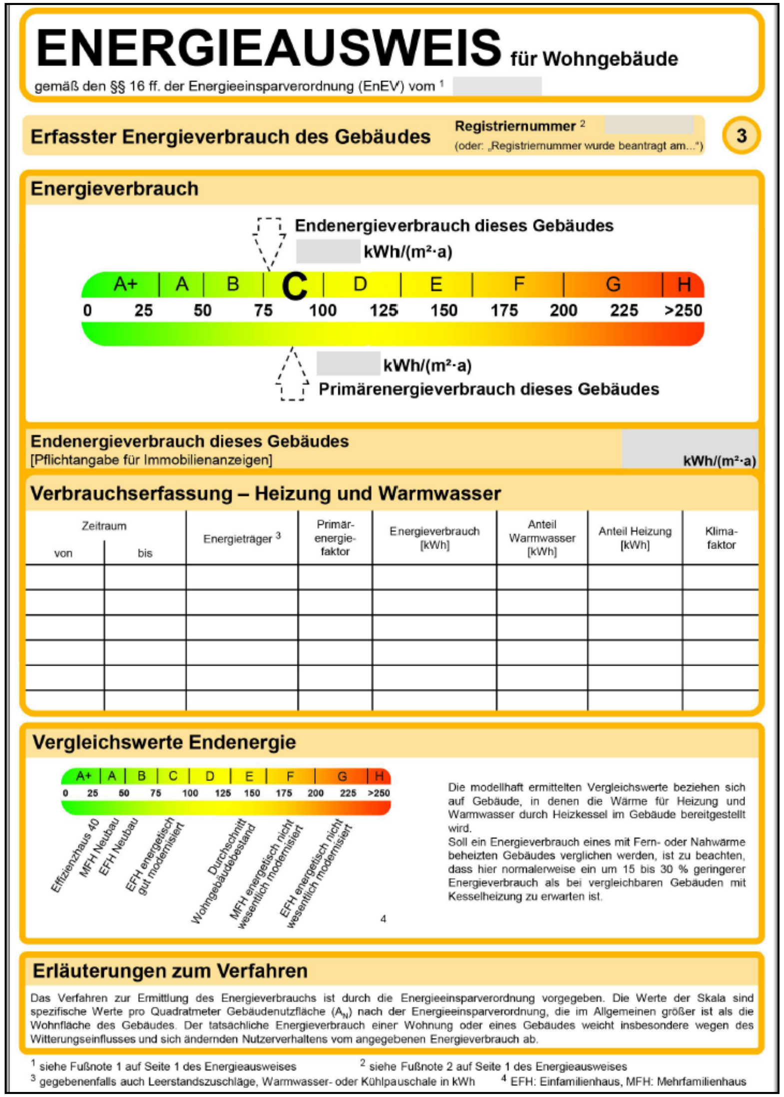
Effizienzhaus 40
MFH Neubau
EFH Neubau
EFH energetisch gut modernisiert
Durchschnitt Wohngebäudebestand
MFH energetisch nicht wesentlich modernisiert
EFH energetisch nicht wesentlich modernisiert
7

Erläuterungen zum Berechnungsverfahren

Die Energieeinsparverordnung lässt für die Berechnung des Energiebedarfs unterschiedliche Verfahren zu, die im Einzelfall zu unterschiedlichen Ergebnissen führen können. Insbesondere wegen standardisierter Randbedingungen erlauben die angegebenen Werte keine Rückschlüsse auf den tatsächlichen Energieverbrauch. Die ausgewiesenen Bedarfswerte der Skala sind spezifische Werte nach der EnEV pro Quadratmeter Gebäudenutzfläche (A_N), die im Allgemeinen größer ist als die Wohnfläche des Gebäudes.

[1] siehe Fußnote 1 auf Seite 1 des Energieausweises
[2] siehe Fußnote 2 auf Seite 1 des Energieausweises
[3] freiwillige Angabe
[4] nur bei Neubau sowie bei Modernisierung im Fall des § 16 Absatz 1 Satz 3 EnEV
[5] nur bei Neubau
[6] nur bei Neubau im Fall der Anwendung von § 7 Absatz 1 Nummer 2 EEWärmeG
[7] EFH: Einfamilienhaus, MFH: Mehrfamilienhaus

Sheet 3



ENERGIEAUSWEIS für Wohngebäude

gemäß den §§ 16 ff. der Energieeinsparverordnung (EnEV) vom [1]

Erfasster Energieverbrauch des Gebäudes

Registriernummer [2]
(oder: „Registriernummer wurde beantragt am...")

3

Energieverbrauch

Endenergieverbrauch dieses Gebäudes
kWh/(m²·a)

A+ | A | B | C | D | E | F | G | H

0 25 50 75 100 125 150 175 200 225 >250

kWh/(m²·a)
Primärenergieverbrauch dieses Gebäudes

Endenergieverbrauch dieses Gebäudes
[Pflichtangabe für Immobilienanzeigen]
kWh/(m²·a)

Verbrauchserfassung – Heizung und Warmwasser

Zeitraum von	Zeitraum bis	Energieträger [3]	Primär-energie-faktor	Energieverbrauch [kWh]	Anteil Warmwasser [kWh]	Anteil Heizung [kWh]	Klima-faktor

Vergleichswerte Endenergie

Die modellhaft ermittelten Vergleichswerte beziehen sich auf Gebäude, in denen die Wärme für Heizung und Warmwasser durch Heizkessel im Gebäude bereitgestellt wird.
Soll ein Energieverbrauch eines mit Fern- oder Nahwärme beheizten Gebäudes verglichen werden, ist zu beachten, dass hier normalerweise ein um 15 bis 30 % geringerer Energieverbrauch als bei vergleichbaren Gebäuden mit Kesselheizung zu erwarten ist.

Erläuterungen zum Verfahren

Das Verfahren zur Ermittlung des Energieverbrauchs ist durch die Energieeinsparverordnung vorgegeben. Die Werte der Skala sind spezifische Werte pro Quadratmeter Gebäudenutzfläche (A_N) nach der Energieeinsparverordnung, die im Allgemeinen größer ist als die Wohnfläche des Gebäudes. Der tatsächliche Energieverbrauch einer Wohnung oder eines Gebäudes weicht insbesondere wegen des Witterungseinflusses und sich ändernden Nutzerverhaltens vom angegebenen Energieverbrauch ab.

[1] siehe Fußnote 1 auf Seite 1 des Energieausweises
[2] siehe Fußnote 2 auf Seite 1 des Energieausweises
[3] gegebenenfalls auch Leerstandszuschläge, Warmwasser- oder Kühlpauschale in kWh
[4] EFH: Einfamilienhaus, MFH: Mehrfamilienhaus

Sheet 4

ENERGIEAUSWEIS für Wohngebäude

gemäß den §§ 16 ff. der Energieeinsparverordnung (EnEV) vom [1]

Empfehlungen des Ausstellers

Registriernummer [2]
(oder: „Registriernummer wurde beantragt am...")

4

Empfehlungen zur kostengünstigen Modernisierung

Maßnahmen zur kostengünstigen Verbesserung der Energieeffizienz sind ☐ möglich ☐ nicht möglich

Empfohlene Modernisierungsmaßnahmen

Nr.	Bau- oder Anlagenteile	Maßnahmenbeschreibung in einzelnen Schritten	empfohlen: in Zusammenhang mit größerer Modernisierung	empfohlen: als Einzel-maß-nahme	(freiwillige Angaben): geschätzte Amortisa-tionszeit	(freiwillige Angaben): geschätzte Kosten pro eingesparte Kilowatt-stunde Endenergie
			☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		

☐ weitere Empfehlungen auf gesondertem Blatt

Hinweis: Modernisierungsempfehlungen für das Gebäude dienen lediglich der Information.
Sie sind nur kurz gefasste Hinweise und kein Ersatz für eine Energieberatung.

Genauere Angaben zu den Empfehlungen sind erhältlich bei/unter:	

Ergänzende Erläuterungen zu den Angaben im Energieausweis (Angaben freiwillig)

[1] siehe Fußnote 1 auf Seite 1 des Energieausweises
[2] siehe Fußnote 2 auf Seite 1 des Energieausweises

Sheet 5

ENERGIEAUSWEIS für Wohngebäude

gemäß den §§ 16 ff. der Energieeinsparverordnung (EnEV) vom [1]

Erläuterungen

5

Angabe Gebäudeteil – Seite 1

Bei Wohngebäuden, die zu einem nicht unerheblichen Anteil zu anderen als Wohnzwecken genutzt werden, ist die Ausstellung des Energieausweises gemäß dem Muster nach Anlage 6 auf den Gebäudeteil zu beschränken, der getrennt als Wohngebäude zu behandeln ist (siehe im Einzelnen § 22 EnEV). Dies wird im Energieausweis durch die Angabe „Gebäudeteil" deutlich gemacht.

Erneuerbare Energien – Seite 1

Hier wird darüber informiert, wofür und in welcher Art erneuerbare Energien genutzt werden. Bei Neubauten enthält Seite 2 (Angaben zum EEWärmeG) dazu weitere Angaben.

Energiebedarf – Seite 2

Der Energiebedarf wird hier durch den Jahres-Primärenergiebedarf und den Endenergiebedarf dargestellt. Diese Angaben werden rechnerisch ermittelt. Die angegebenen Werte werden auf der Grundlage der Bauunterlagen bzw. gebäudebezogener Daten und unter Annahme von standardisierten Randbedingungen (z. B. standardisierte Klimadaten, definiertes Nutzerverhalten, standardisierte Innentemperatur und innere Wärmegewinne usw.) berechnet. So lässt sich die energetische Qualität des Gebäudes unabhängig vom Nutzerverhalten und von der Wetterlage beurteilen. Insbesondere wegen der standardisierten Randbedingungen erlauben die angegebenen Werte keine Rückschlüsse auf den tatsächlichen Energieverbrauch.

Primärenergiebedarf – Seite 2

Der Primärenergiebedarf bildet die Energieeffizienz des Gebäudes ab. Er berücksichtigt neben der Endenergie auch die so genannte „Vorkette" (Erkundung, Gewinnung, Verteilung, Umwandlung) der jeweils eingesetzten Energieträger (z. B. Heizöl, Gas, Strom, erneuerbare Energien etc.). Ein kleiner Wert signalisiert einen geringen Bedarf und damit eine hohe Energieeffizienz sowie eine die Ressourcen und die Umwelt schonende Energienutzung. Zusätzlich können die mit dem Energiebedarf verbundenen CO_2-Emissionen des Gebäudes freiwillig angegeben werden.

Energetische Qualität der Gebäudehülle – Seite 2

Angegeben ist der spezifische, auf die wärmeübertragende Umfassungsfläche bezogene Transmissionswärmeverlust (Formelzeichen in der EnEV: H_T'). Er beschreibt die durchschnittliche energetische Qualität aller wärmeübertragenden Umfassungsflächen (Außenwände, Decken, Fenster etc.) eines Gebäudes. Ein kleiner Wert signalisiert einen guten baulichen Wärmeschutz. Außerdem stellt die EnEV Anforderungen an den sommerlichen Wärmeschutz (Schutz vor Überhitzung) eines Gebäudes.

Endenergiebedarf – Seite 2

Der Endenergiebedarf gibt die nach technischen Regeln berechnete, jährlich benötigte Energiemenge für Heizung, Lüftung und Warmwasserbereitung an. Er wird unter Standardklima- und Standardnutzungsbedingungen errechnet und ist ein Indikator für die Energieeffizienz eines Gebäudes und seiner Anlagentechnik. Der Endenergiebedarf ist die Energiemenge, die dem Gebäude unter der Annahme von standardisierten Bedingungen und unter Berücksichtigung der Energieverluste zugeführt werden muss, damit die standardisierte Innentemperatur, der Warmwasserbedarf und die notwendige Lüftung sichergestellt werden können. Ein kleiner Wert signalisiert einen geringen Bedarf und damit eine hohe Energieeffizienz.

Angaben zum EEWärmeG – Seite 2

Nach dem EEWärmeG müssen Neubauten in bestimmtem Umfang erneuerbare Energien zur Deckung des Wärme- und Kältebedarfs nutzen. In dem Feld „Angaben zum EEWärmeG" sind die Art der eingesetzten erneuerbaren Energien und der prozentuale Anteil der Pflichterfüllung abzulesen. Das Feld „Ersatzmaßnahmen" wird ausgefüllt, wenn die Anforderungen des EEWärmeG teilweise oder vollständig durch Maßnahmen zur Einsparung von Energie erfüllt werden. Die Angaben dienen gegenüber der zuständigen Behörde als Nachweis des Umfangs der Pflichterfüllung durch die Ersatzmaßnahme und der Einhaltung der für das Gebäude geltenden verschärften Anforderungswerte der EnEV.

Endenergieverbrauch – Seite 3

Der Endenergieverbrauch wird für das Gebäude auf der Basis der Abrechnungen von Heiz- und Warmwasserkosten nach der Heizkostenverordnung oder auf Grund anderer geeigneter Verbrauchsdaten ermittelt. Dabei werden die Energieverbrauchsdaten des gesamten Gebäudes und nicht der einzelnen Wohneinheiten zugrunde gelegt. Der erfasste Energieverbrauch für die Heizung wird anhand der konkreten örtlichen Wetterdaten und mithilfe von Klimafaktoren auf einen deutschlandweiten Mittelwert umgerechnet. So führt beispielsweise ein hoher Verbrauch in einem einzelnen harten Winter nicht zu einer schlechteren Beurteilung des Gebäudes. Der Endenergieverbrauch gibt Hinweise auf die energetische Qualität des Gebäudes und seiner Heizungsanlage. Ein kleiner Wert signalisiert einen geringen Verbrauch. Ein Rückschluss auf den künftig zu erwartenden Verbrauch ist jedoch nicht möglich; insbesondere können die Verbrauchsdaten einzelner Wohneinheiten stark differieren, weil sie von der Lage der Wohneinheiten im Gebäude, von der jeweiligen Nutzung und dem individuellen Verhalten der Bewohner abhängen.

Im Fall längerer Leerstände wird hierfür ein pauschaler Zuschlag rechnerisch bestimmt und in die Verbrauchserfassung einbezogen. Im Interesse der Vergleichbarkeit wird bei dezentralen, in der Regel elektrisch betriebenen Warmwasseranlagen der typische Verbrauch über eine Pauschale berücksichtigt: Gleiches gilt für den Verbrauch von eventuell vorhandenen Anlagen zur Raumkühlung. Ob und inwieweit die genannten Pauschalen in die Erfassung eingegangen sind, ist der Tabelle „Verbrauchserfassung" zu entnehmen.

Primärenergieverbrauch – Seite 3

Der Primärenergieverbrauch geht aus dem für das Gebäude ermittelten Endenergieverbrauch hervor. Wie der Primärenergiebedarf wird er mithilfe von Umrechnungsfaktoren ermittelt, die die Vorkette der jeweils eingesetzten Energieträger berücksichtigen.

Pflichtangaben für Immobilienanzeigen – Seite 2 und 3

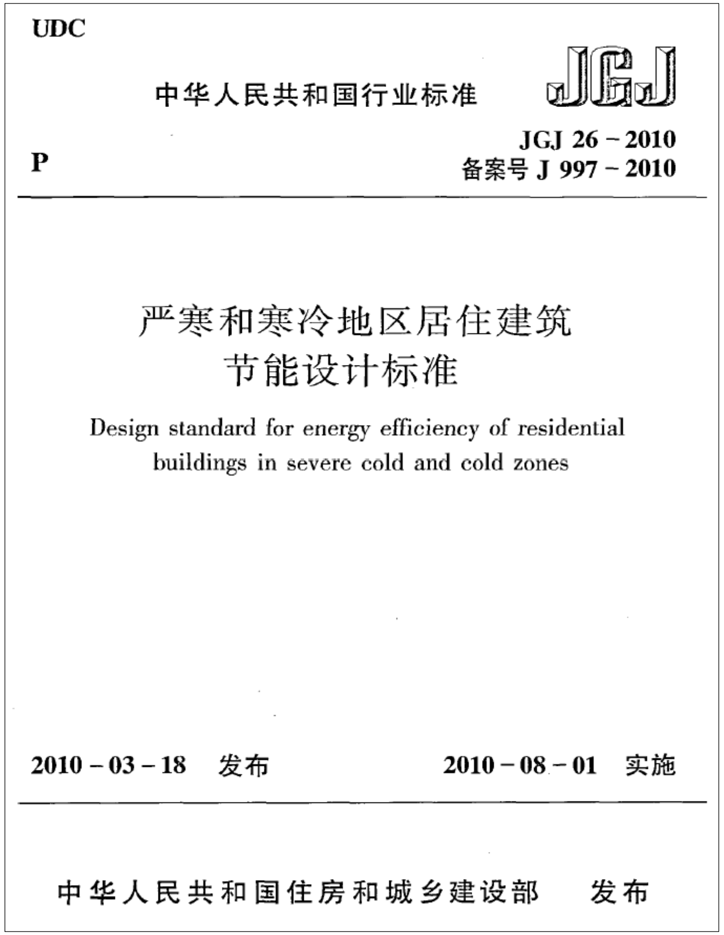
Nach der EnEV besteht die Pflicht, in Immobilienanzeigen die in § 16a Absatz 1 genannten Angaben zu machen. Die dafür erforderlichen Angaben sind dem Energieausweis zu entnehmen, je nach Ausweisart der Seite 2 oder 3.

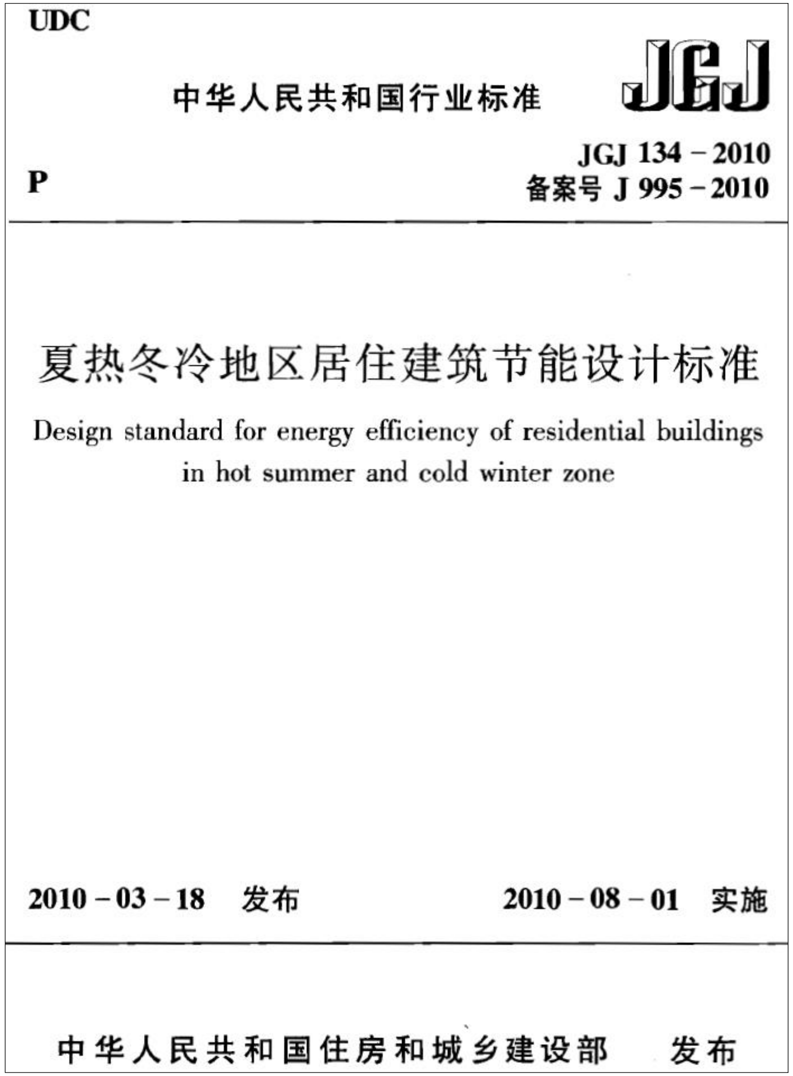
Vergleichswerte – Seite 2 und 3

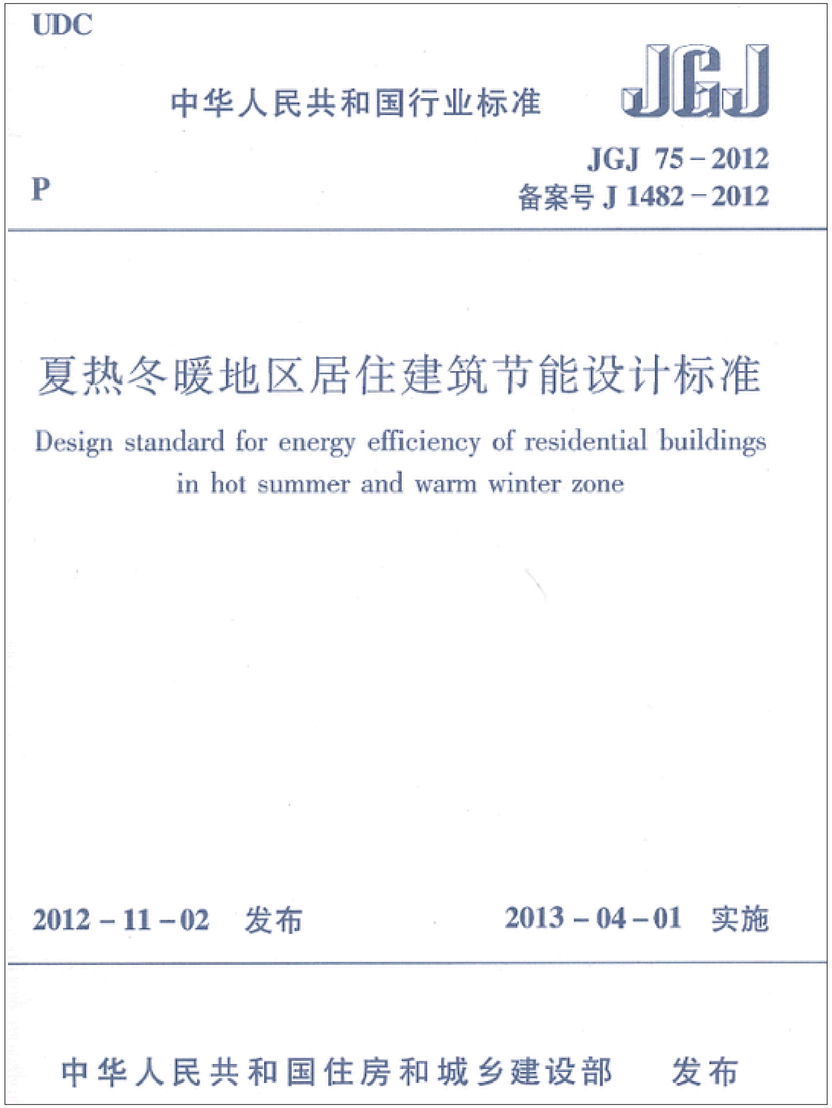
Die Vergleichswerte auf Endenergieebene sind modellhaft ermittelte Werte und sollen lediglich Anhaltspunkte für grobe Vergleiche der Werte dieses Gebäudes mit den Vergleichswerten anderer Gebäude sein. Es sind Bereiche angegeben, innerhalb derer ungefähr die Werte für die einzelnen Vergleichskategorien liegen.

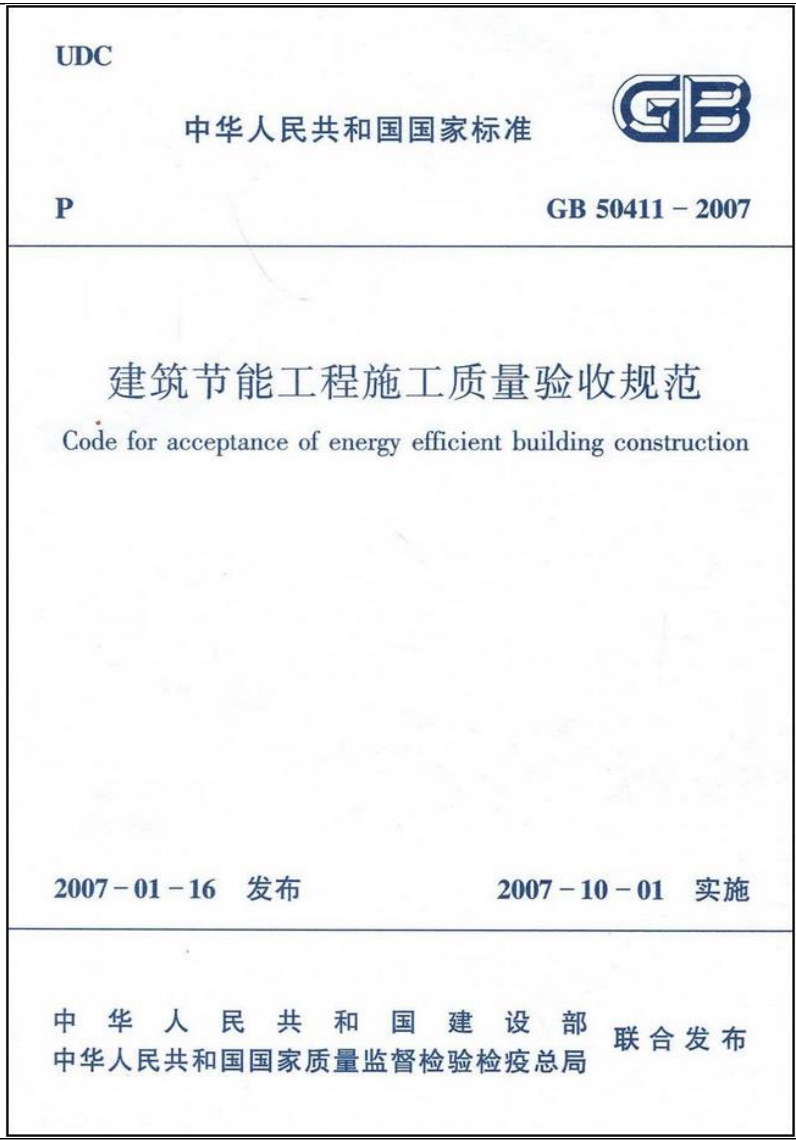
[1] siehe Fußnote 1 auf Seite 1 des Energieausweises

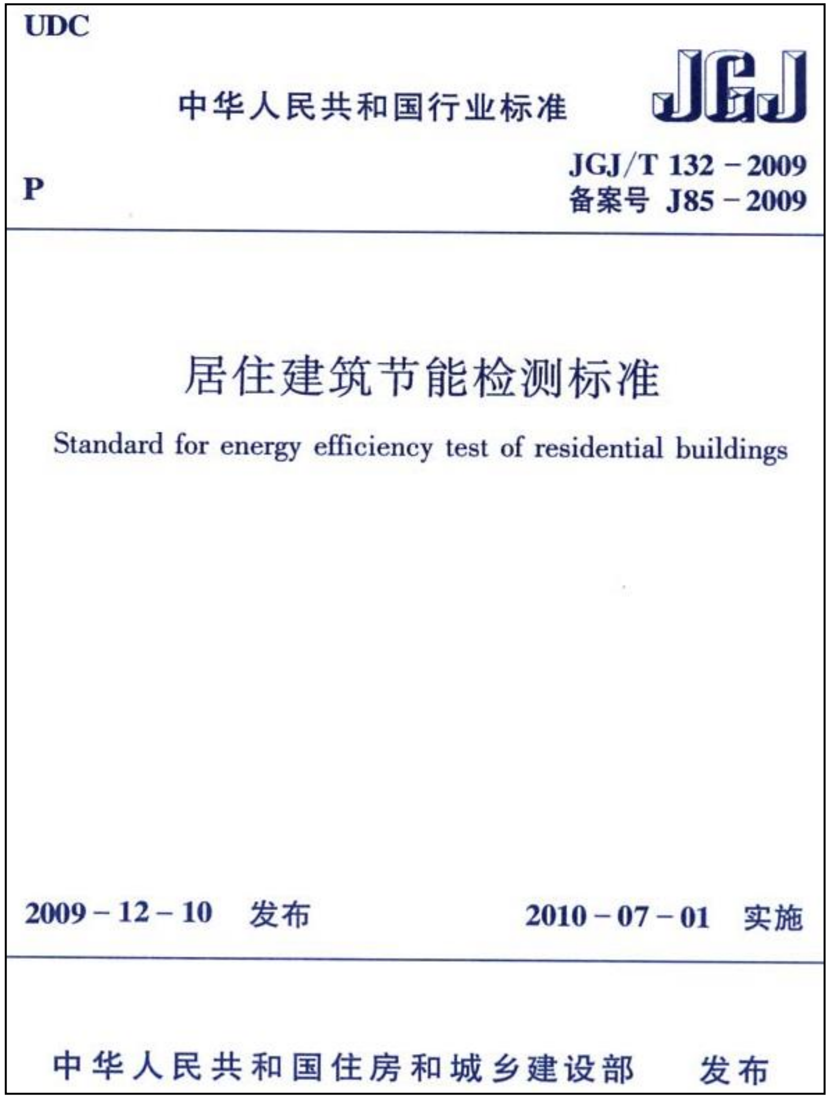
Appendix 2 Design standards for energy efficiency of residential buildings in China

Climate zone	Design standards	Application
Design standard for energy efficiency of residential buildings in severe cold and cold zones.	 UDC 中华人民共和国行业标准 JGJ P JGJ 26－2010 备案号 J 997－2010 严寒和寒冷地区居住建筑 节能设计标准 Design standard for energy efficiency of residential buildings in severe cold and cold zones 2010－03－18 发布 2010－08－01 实施 中华人民共和国住房和城乡建设部 发布	Note: - JGJ: Design Standard of construction industry (cn.: 建工行业建设标准) - JG: Construction industry (cn: 建工) - J: Design Standards (cn: 建设标准) JG/T: suggested Design Standards (cn: 推荐性国家标准)

Design standard for energy efficiency of residential buildings in hot summer and cold winter zone	 UDC 中华人民共和国行业标准 JGJ P JGJ 134－2010 备案号 J 995－2010 夏热冬冷地区居住建筑节能设计标准 Design standard for energy efficiency of residential buildings in hot summer and cold winter zone 2010－03－18 发布 2010－08－01 实施 中华人民共和国住房和城乡建设部 发布	

Design standard for energy efficiency of residential buildings in hot summer and warm winter zone	 UDC 中华人民共和国行业标准 JGJ P JGJ 75－2012 备案号 J 1482－2012 夏热冬暖地区居住建筑节能设计标准 Design standard for energy efficiency of residential buildings in hot summer and warm winter zone 2012－11－02 发布 2013－04－01 实施 中华人民共和国住房和城乡建设部 发布	

Code for acceptance of energy efficient building construction	 UDC 中华人民共和国国家标准 P GB 50411－2007 建筑节能工程施工质量验收规范 Code for acceptance of energy efficient building construction 2007－01－16 发布 2007－10－01 实施 中 华 人 民 共 和 国 建 设 部 中华人民共和国国家质量监督检验检疫总局 联 合 发 布	

Standard for energy efficiency test of residential buildings	 UDC 中华人民共和国行业标准 JGJ P JGJ/T 132－2009 备案号 J85－2009 居住建筑节能检测标准 Standard for energy efficiency test of residential buildings 2009－12－10 发布 2010－07－01 实施 中华人民共和国住房和城乡建设部 发布	

Appendix 3 Grade Classification of Green Buildings in China (Residential)

Level	Regular options (40 options)						Premium options (9 options)	Relative energy saving rate η
	Land saving and outdoor environment (8 options)	Energy efficiency and utilization (6 options)	Water efficiency and utilization (6 options)	Materials saving and utilization (7 options)	Indoor environmental quality (6 options)	Operation and management (7 options)		
★	4	2	3	3	2	5	N.A.	0 < η < 15%
★★	6	3	4	4	3	6	2	15 < η < 30%
★★★	7	4	6	5	4	7	4	η ≥ 30%

Source: Green Building Evaluation Standards, 2006. (Shui and Li, 2012, p. 43)

(Remark: Mandatory options are controlling options and have to be firstly completed if any building is going to be assessed. The relative energy saving rate η is a theoretical value that describes how much more energy-efficiency does the test residential building achieve after energy efficiency measures than the current design standards for reference building.)

Appendix 4 Checklist of LEED v4 for Homes Design and Construction: Homes and Multifamily Lowrise

Y	?	N			
			Credit	Integrative Process	**2**
0	**0**	**0**	**Location and Transportation**		**15**
Y			Prereq	Floodplain Avoidance	Required
				PERFORMANCE PATH	
			Credit	LEED for Neighborhood Development Location	15
				PRESCRIPTIVE PATH	
			Credit	Site Selection	8
			Credit	Compact Development	3
			Credit	Community Resources	2
			Credit	Access to Transit	2
0	**0**	**0**	**Sustainable Sites**		**7**
Y			Prereq	Construction Activity Pollution Prevention	Required
Y			Prereq	No Invasive Plants	Required
			Credit	Heat Island Reduction	2
			Credit	Rainwater Management	3
			Credit	Non-Toxic Pest Control	2
0	**0**	**0**	**Water Efficiency**		**12**
Y			Prereq	Water Metering	Required
				PERFORMANCE PATH	
			Credit	Total Water Use	12
				PRESCRIPTIVE PATH	
			Credit	Indoor Water Use	6
			Credit	Outdoor Water Use	4
0	**0**	**0**	**Energy and Atmosphere**		**38**
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Energy Metering	Required
Y			Prereq	Education of the Homeowner, Tenant or Building Manager	Required
				PERFORMANCE PATH	
			Credit	Annual Energy Use	29
				BOTH PATHS	
			Credit	Efficient Hot Water Distribution System	5
			Credit	Advanced Utility Tracking	2
			Credit	Active Solar Ready Design	1
			Credit	HVAC Start-Up Credentialing	1
				PRESCRIPTIVE PATH	
Y			Prereq	Home Size	Required
			Credit	Building Orientation for Passive Solar	3
			Credit	Air Infiltration	2
			Credit	Envelope Insulation	2
			Credit	Windows	3
			Credit	Space Heating & Cooling Equipment	4

				EA PRESCRIPTIVE PATH (continued)	
			Credit	Heating & Cooling Distribution Systems	3
			Credit	Efficient Domestic Hot Water Equipment	3
			Credit	Lighting	2
			Credit	High Efficiency Appliances	2
			Credit	Renewable Energy	4
0	**0**	**0**		**Materials and Resources**	**10**
Y			Prereq	Certified Tropical Wood	Required
Y			Prereq	Durability Management	Required
			Credit	Durability Management Verification	1
			Credit	Environmentally Preferable Products	4
			Credit	Construction Waste Management	3
			Credit	Material Efficient Framing	2
0	**0**	**0**		**Indoor Environmental Quality**	**16**
Y			Prereq	Ventila-tion	Required
Y			Prereq	Combustion Venting	Required
Y			Prereq	Garage Pollutant Protection	Required
Y			Prereq	Radon-Resistant Construction	Required
Y			Prereq	Air FIl-tering	Required
Y			Prereq	Environmental Tobacco Smoke	Required
Y			Prereq	Compartmentalization	Required
			Credit	Enhanced Ventilation	3
			Credit	Contaminant Control	2
			Credit	Balancing of Heating and Cooling Distribution Systems	3
			Credit	Enhanced Compartmentalization	1
			Credit	Enhanced Combustion Venting	2
			Credit	Enhanced Garage Pollutant Protection	2
			Credit	Low Emitting Products	3
0	**0**	**0**		**Innovation**	**6**
Y			Prereq	Preliminary Rating	Required
			Credit	Innovation	5
			Credit	LEED AP Homes	1
0	**0**	**0**		**Regional Pri-ority**	**4**
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
0	**0**	**0**		**TOTALS** Possible Points:	**110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

Source: “LEED v4 for Building and Construction: Homes and Multifamily Lowrise”

Appendix 5 Checklist of LEED v4 for Homes Design and Construction: Multi-family Midrise

Y	?	N			
			Credit	Integrative Process	**2**
0	**0**	**0**	**Location and Transportation**		**15**
Y			Prereq	Floodplain Avoidance	Required
			PERFORMANCE PATH		
			Credit	LEED for Neighborhood Development Location	15
			PRESCRIPTIVE PATH		
			Credit	Site Selection	8
			Credit	Compact Development	3
			Credit	Community Resources	2
			Credit	Access to Transit	2
0	**0**	**0**	**Sustainable Sites**		**7**
Y			Prereq	Construction Activity Pollution Prevention	Required
Y			Prereq	No Invasive Plants	Required
			Credit	Heat Island Reduction	2
			Credit	Rainwater Management	3
			Credit	Non-Toxic Pest Control	2
0	**0**	**0**	**Water Efficiency**		**12**
Y			Prereq	Water Metering	Required
			PERFORMANCE PATH		
			Credit	Total Water Use	12
			PRESCRIPTIVE PATH		
			Credit	Indoor Water Use	6
			Credit	Outdoor Water Use	4
0	**0**	**0**	**Energy and Atmosphere**		**37**
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Energy Metering	Required
Y			Prereq	Education of the Homeowner, Tenant or Building Manager	Required
			Credit	Annual Energy Use	30
			Credit	Efficieng Hot Water Distribution	5
			Credit	Advanced Utility Tracking	2
0	**0**	**0**	**Materials and Resources**		**9**
Y			Prereq	Certified Tropical Wood	Required
Y			Prereq	Durability Management	Required
			Credit	Durability Management Verification	1
			Credit	Environmentally Preferable Products	5
			Credit	Construction Waste Management	3
0	**0**	**0**	**Indoor Environmental Quality**		**18**
Y			Prereq	Ventilation	Required
Y			Prereq	Combustion Venting	Required
Y			Prereq	Garage Pollutant Protection	Required

Y			Prereq	Radon-Resistant Construction	Required
Y			Prereq	Air FIltering	Required
Y			Prereq	Environmental Tobacco Smoke	Required
Y			Prereq	Compartmentalization	Required
			Credit	Enhanced Ventilation	3
			Credit	Contaminant Control	2
			Credit	Balancing of Heating and Cooling Distribution Systems	3
			Credit	Enhanced Compartmentalization	3
			Credit	Enhanced Combustion Venting	2
			Credit	Enhanced Garage Pollutant Protection	1
			Credit	Low Emitting Products	3
			Credit	No Environmental Tobacco Smoke	1
0	**0**	**0**	**Innovation**		**6**
Y			Prereq	Preliminary Rating	Required
			Credit	Innovation	5
			Credit	LEED AP Homes	1
0	**0**	**0**	**Regional Priority**		**4**
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
0	**0**	**0**	**TOTALS**	Possible Points:	**110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points**, Platinum:** 80 to 110

Source: “LEED v4 for Building and Construction: Homes and Multifamily Midrise”.

Appendix 6 Energy-related CO_2 emissions by sector, 2013

Energy-related CO_2 emissions by sector, 2013 (Mio. t CO_2-Äquivalente)							
	Manufacturing industries and construction	Transport	Electricity and heat production	Residential	Other sectors	Other energy ind. own use*	Total
World	6114,8	7384,9	13655,6	1868,7	1491,8	1674	32189,8
Germany	92,7	152,4	342,3	99	49,8	23,4	759,6
China (incl. Hong Kong)	2813,1	760,2	4416,9	330,6	335,1	367,4	9023,3
U.S.	422,1	1700,8	2128,3	322,9	263,2	282,5	5119,8
EU-28	414	861,2	1254,2	415,8	239,3	155,5	3340

*: includes emissions from own use in petroleum refining, the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries.

(Data source: CO_2 emissions from fuel combustion HIGHLIGHTS 2015 Edition, pp.66-68)

Appendix 7 Heating Degree Days of Darmstadt in 2011 and 2012[153]

2011	Heating Degree Days		Outdoor temperatur	Outdoor temeprature
	Limit-15°C	Heating days		of heating days
Month	[Kd]	[d]	[°C]	[°C]
January	422	31	1.4	1.4
February	371	28	1.8	1.8
March	256	31	6.7	6.7
April	67	22	13.2	12.0
May	38	12	15.5	11.8
June	9	6	17.4	13.5
July	10	8	17.0	13.7
August	4	4	19.1	14.1
September	12	10	16.7	13.8
October	171	25	9.9	8.2
November	326	30	4.1	4.1
December	332	31	4.3	4.3
Year	**2017**	**238**	**0.0**	**6.5**

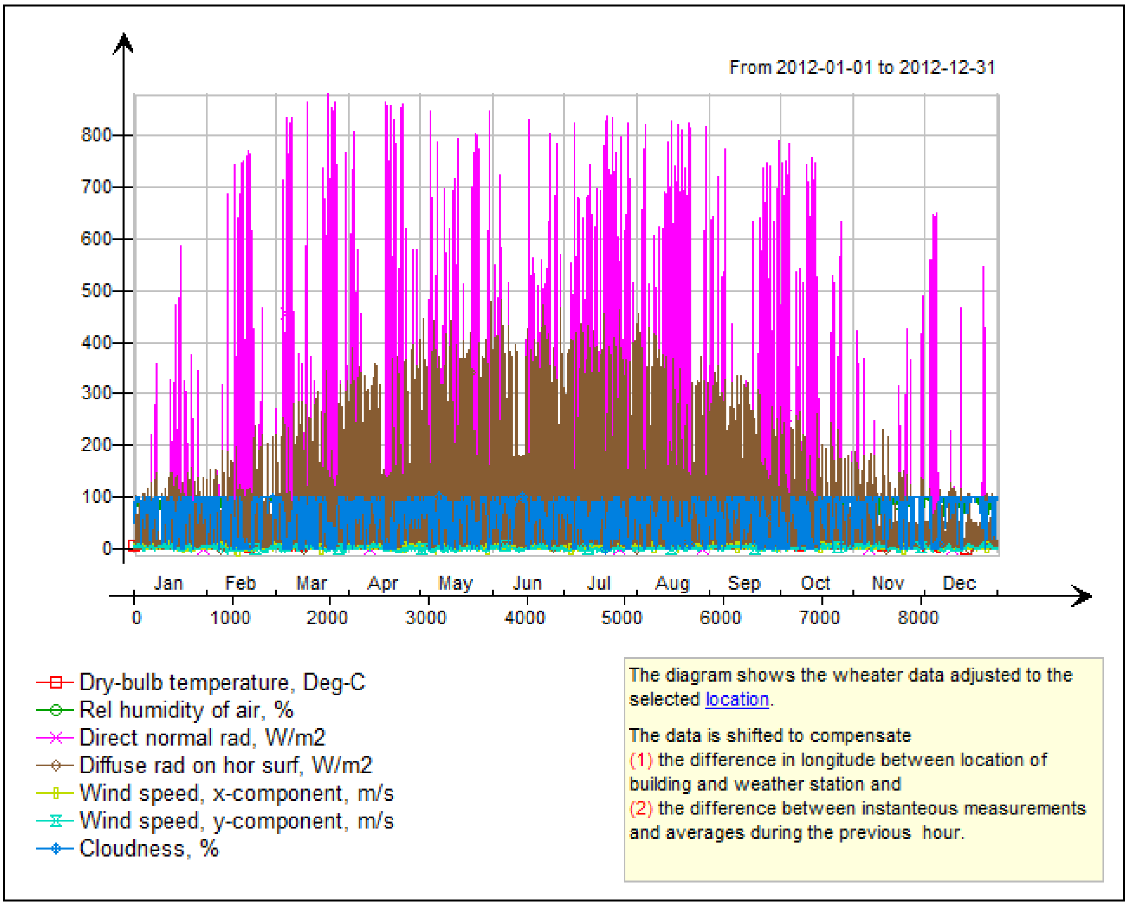
2012	Heating Degree Days		Outdoor temperatur	Outdoor temeprature
	Limit-15°C	Heating days		of heating days
Month	[Kd]	[d]	[°C]	[°C]
January	385	31	2.6	2.6
February	493	29	-2.0	-2.0
March	210	31	8.2	8.2
April	179	26	9.6	8.1
May	41	10	16.5	10.9
June	11	9	17.3	13.8
July	0	1	18.7	14.9
August	0	0	20.5	
September	41	16	15.0	12.5
October	188	30	9.0	8.7
November	288	30	5.4	5.4
December	385	31	2.6	2.6
Year	2219	244	10.4	5.9

For example January 2011, the HDD = (15-1.4)°C * 31 days = 422 Kd.

[153] „Gradtagszahlen Deutschland“ by German Institute of Housing and Environment, Institut Wohnen und Umwelt, IWU.

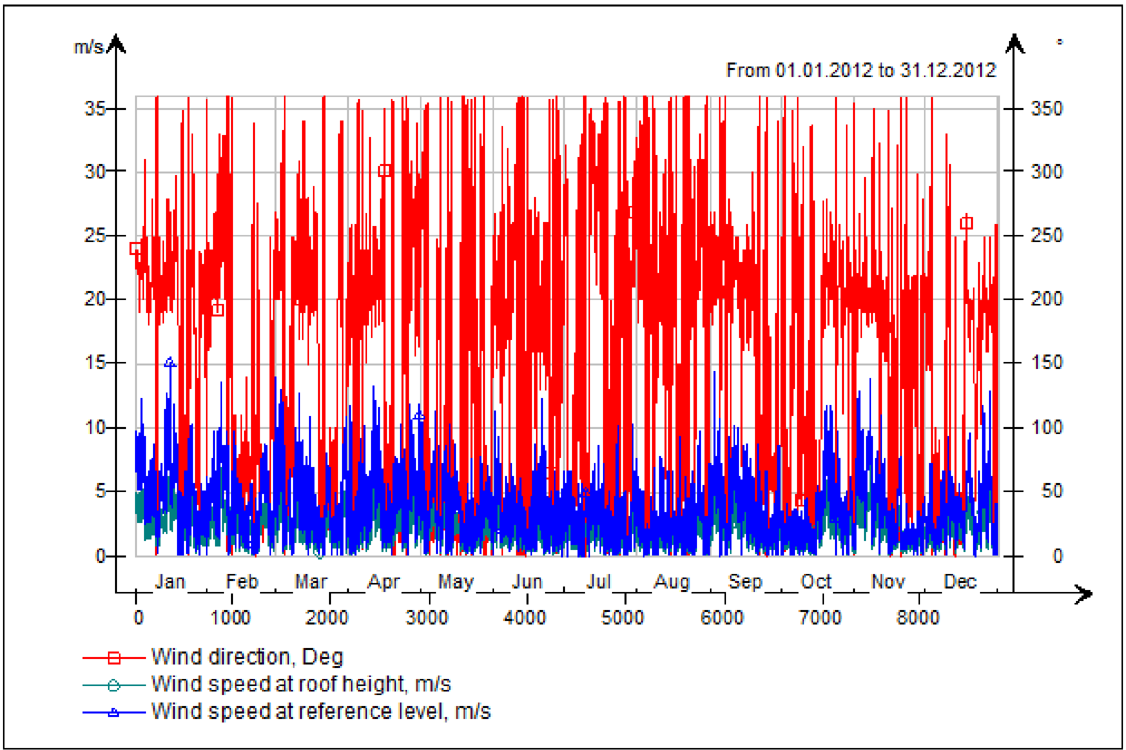
Appendix 8 Climate file of Darmstadt, 2012 (based on weather data from DWD and generated by IDA ICE 4.7.1)

	Variables						
	Dry-bulb temperature, Deg-C	Rel humidity of air, %	Direct normal rad, W/m2	Diffuse rad on hor surf, W/m2	Wind speed, x-component, m/s	Wind speed, y-component, m/s	Cloudness, %
January	2.4	83.3	15.5	21.5	2.6	2.5	76.4
February	1.9	78.2	57.9	33.7	0.1	-0.1	64.7
March	5.6	72.6	102.9	61.4	0.6	0.4	54.8
April	9.2	68.8	104.9	95.5	1.9	0.9	62.4
May	15.0	68.8	124.7	116.0	-0.3	-0.9	60.4
June	16.4	72.4	90.5	125.6	1.0	1.2	71.0
July	19.4	66.7	148.6	123.3	0.6	-0.9	56.1
August	18.8	68.9	137.7	100.2	1.3	0.4	55.0
September	14.8	72.4	95.8	75.6	1.6	1.4	58.1
October	10.3	83.5	69.7	44.8	0.8	1.2	59.8
November	4.6	87.6	16.5	25.6	0.6	2.0	76.9
December	1.8	86.5	20.4	15.9	0.3	1.0	80.0
mean	10.0	75.8	82.3	70.0	0.9	0.7	64.6
mean*8784.0 h	88269.8	665936.7	722659.0	614952.0	7954.6	6563.6	567460.4
min	1.8	66.7	15.5	15.9	-0.3	-0.9	54.8
max	19.4	87.6	148.6	125.6	2.6	2.5	80.0



Appendix 9 Wind file (speed, direction) of case building in Darmstadt, 2012 (based on weather data from DWD and geographic location of case building, and generated by IDA ICE 4.7.1)

	Variables		
	Wind direction, Deg	Wind speed at roof height, m/s	Wind speed at reference level, m/s
January	196.7	2.517	4.966
February	134.3	2.117	4.178
March	160.4	2.024	3.993
April	174.9	2.344	4.626
May	124.7	1.826	3.603
June	174.1	1.625	3.206
July	172.6	1.445	2.851
August	201.8	1.258	2.483
September	178.6	1.84	3.63
October	153.1	1.573	3.105
November	149.2	1.951	3.85
December	127.6	1.834	3.618
mean	162.4	1.86	3.671
mean*8784.0 h	1426531.8	16341.7	32248.0
min	124.7	1.258	2.483
max	201.8	2.517	4.966



Wind measurement height = 10.0 m, city center.

Appendix 10 Structure of residential building typology for Hessen Germany

Gebäudetypen		Baualtersklassen (Hessen)							
		A	B	C	D	E	F	G	H
freistehende Ein-familienhäuser	EFH	-1918	-1918	1919 -1948	1949 -1957	1958 -1968	1969 -1978	1979 -1983	1984 -1987
Reihenhäuser	RH		-1918	1919 -1948	1949 -1957	1958 -1968	1969 -1978	1979 -1983	1984 -1987
kleine Mehrfa-milienhäuser	KMH	-1918	-1918	1919 -1948	1949 -1957	1958 -1968	1969 -1978	1979 -1983	1984 -1987
große Mehrfami-lienhäuser	GMH		-1918	1919 -1948	1949 -1957	1958 -1968	1969 -1978		
Hochhäuser	HH						1969 -1978		

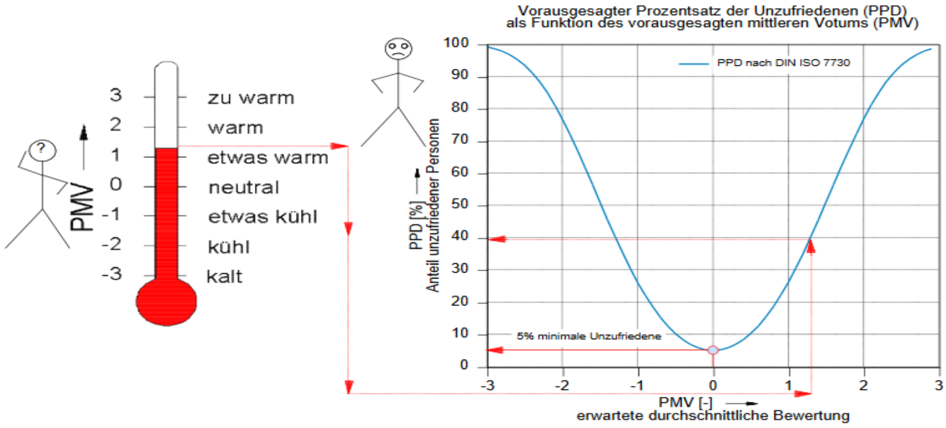
A: Fachwerkbauten bis zum Ende des 1. Weltkriegs
B: Massivbauten bis zum Ende des 1. Weltkriegs
C: Bauten zwischen 1. und 2. Weltkrieg
D: in Nachkriegsjahren aufgrund angespannter Materialmärkte, niedrigen Anforderungen in den Bauvorschriften und des hohen Wohnungsbedarfs qualitativ einfache Baukonstruktionen mit geringen Materialstärken; Anforderungen an den Wärmeschutz nach DIN 4108 nicht immer eingehalten.
E: Mindestanforderungen nach der DIN 4108 meist eingehalten und gelegentlich übererfüllt; am Ende dieses Zeitraumes Gebäude- und Wohnungszählung 1968 mit umfangreichen Gebäudestrukturdaten;
F: ergänzende Bestimmungen zur DIN 4108; erste Ölpreiskrise; erforderlicher Mindestwärmeschutz nach der DIN 4108 meist übertroffen;
G: 1977: erste Wärmeschutzverordnung (I. WSchVO); 1978: 1%-Wohnungsstichprobe;
H: 1984: II. WSchVO; jüngsten Baujahrgänge unter den gegenwärtig geltenden Rahmenbedingungen des Wohnungsbaus erfasst; 1987 Volkszählung mit Wohnungszählung.

(Source: "Die Hessische Gebäudetypologie", Hessische Energiespar-Aktion, 2003)

Code *(kursiv: TABULA Code)*	**Bild eines Beispiel-gebäudes**	**Bau-alters-klasse**	**typische Bauweise: häufiges Erscheinungsbild / energierelevante Merkmale (Baukörper / Konstruktionen)**
GMH_B *DE.N.AB.02.Gen*		1860 ... 1918	Gründerzeit-Gebäude, meist 4- bis 5-geschossig, mit Satteldach; mit oder ohne ausgebautem Dachgeschoss; Holzbalkendecken; häufig Mauerwerk aus Vollziegeln oder regionalen Natursteinen, teilweise zweischalig; bisweilen erhaltenswerte bzw. denkmalgeschützte Fassade; Kellerdecke als Kappengewölbe oder Kappendecke
GMH_C *DE.N.AB.03.Gen*		1919 ... 1948	typisch 5- bis 6-geschossig, mit Sattel- oder Flachdach (Kaltdach), Dachgeschoss selten ausgebaut (Trockenboden); Holzbalkendecken oder massive Decken; ein- oder zweischaliges Mauerwerk aus Vollziegeln oder regionalen Natursteinen, in Norddeutschland Klinkerschale; Kellerdecke massiv (Stahlsteindecke, Ortbetondecke o.ä.)
GMH_D *DE.N.AB.04.Gen*		1949 ... 1957	typisch 5- bis 8-geschossig, mit Sattel- oder Flachdach (Kaltdach), Dachgeschoss selten ausgebaut (Trockenboden); ein- oder zweischaliges Mauerwerk aus Trümmer-Hohlblocksteinen, Vollziegeln o.ä., in Norddeutschland Klinkerschale; Geschossdecken und Kellerdecke massiv (Stahlbetondecken)
GMH_E *DE.N.AB.05.Gen*		1958 ... 1968	typisch 5- bis 8-geschossig, mit Sattel- oder Flachdach, Dachgeschoss bisweilen beheizt; Betondecken; Mauerwerk aus Hohlblocksteinen, Gitterziegeln o.ä., verputzt; in Norddeutschland meist zweischalig unverputzt; Loggien / Balkone durchgehend betoniert
GMH_F *DE.N.AB.06.Gen*		1969 ... 1978	mehr als 8 Geschosse; Flachdach; Tafel-Bauweise mit Beton-Sandwich-Elementen oder Mauerwerk aus verputzten Gitterziegeln, Kalksandlochsteinen o.ä., in Norddeutschland meist Klinker-Vorsatzschale; Betondecken, Loggien durchgehend betoniert

(Source: „Deutsche Wohngebäudetypologie-Beispielhafte Maßnahmen zur Verbesserung der Energieeffizienz von typischen Wohngebäuden", IWU, 2015)

Appendix 11 PMV and PPD, MET



[PMV and PPD according to DIN EN ISO 7730 (Dentel and Dietrich 2006, p.26)]

Physical activity level	MET
Light intensity activities	(< 3 MET)
- sleeping	0.9
- watching TV	1.0
- writing, desk work, typing	1.5
- walking (2.7 km/h), level ground, strolling, very slow	2.3
- walking (4 km/h)	2.9
Moderate intensity activities	(3~6 MET)
- bicycling, stationary, 50 watts, very light effort	3.0
- walking (4.8 km/h)	3.3
- calisthenics, home exercise, light or moderate effort, general	3.5
- walking (5.5 km/h)	3.6
- bicycling, <10 mph (16 km/h), leisure, to work or for pleasure	4.0
- bicycling, stationary, 100 watts, light effort	5.5
Vigorous intensity activities	(> 6 MET)
- Jogging	7~8
- calisthenics (e.g. pushups, situps, pullups, jumping jacks), heavy, vigorous effort	8.0
- running jogging, in place	8.0
- rope jumping	
1 met corresponds to 58.2 W per m^2 body surface, which is the amount one sitting, inactive person is assumed to emit. In IDA ICE, body surface has been selected to be 1.8 m^2, corresponding to an average adult.	

[Source: Office of Disease Prevention and Health Promotion[154]]

[154] https://health.gov/paguidelines/guidelines/appendix1.aspx

Appendix 12 Example criteria for ventilation rate of residential buildings. Continually operation of ventilation system during the occupancy time.

Category	Air change rate [a]		Living room and bedroom, principle outdoor air flow		Exhaust air flow, l/s		
	l/ (s•m^2)	ACH	l/s, pers [b]	l/s/m^2	Kitchen	Bathroom	Toilet
I	0.49	0.7	10	1.4	28	20	14
II	0.42	0.6	7	1.0	20	15	10
III	0.35	0.5	4	0.6	14	10	7

a The air change rate in l/(s•m^2) corresponds to ceiling height 2.5 m.

b The number of people in an apartment can be estimated by the number of bedrooms. Any existing assumptions at national level must be applied, they may differ in energy and indoor air quality calculations.

Source: DIN EN 15251: 2012-12 - Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics, p.34.

Appendix 13 Schedules of occupancy, lighting and electrical household equipment

Zone 1

Zone 1	2. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
Retiree 1	**Weekdays**	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Retiree 2	**Weekdays**	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living room	**All**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bedroom 1	**All**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
Lighting-Bedroom 2	**All**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	**All**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	**All**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
TV	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	**All**	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	**All**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Computer	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Weekends	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hairdryer	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Weekends	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	**All**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0

Zone 2

Zone 2	2. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
Retiree 1	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Retiree 2	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living room	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bedroom 1	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
Lighting-Bedroom 2	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
TV	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Computer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Weekends	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Weekends	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

Zone 3

Zone 3	1. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30
Retiree 1	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living+bed room	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
TV	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Computer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Weekends	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Zone 3	1. per.	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
Retiree 1	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living+bed room	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
TV	Weekdays	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	Weekdays	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Computer	Weekdays	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Weekends	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

Zone 4

Zone 4	2. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
Retiree	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Full-time employee	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living room	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bedroom 1	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
Lighting-Bedroom 2	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0
Lighting-Kitchen	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
TV	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Laptop	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

Zone 5

Zone 5	2. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
Part-time employee	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Full-time employee	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living room	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
Lighting-Bedroom	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
Lighting-Workroom	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0
TV	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Computer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

Zone 6

Zone 6	1. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
University student	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living+bed room	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Weekend	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Laptop	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

Zone 7

Zone 7	3. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
Full-time employee	**Weekdays**	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Housewife	**Weekdays**	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
School-aged child	**Weekdays**	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living room	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
Lighting-Bedroom 1	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
Lighting-Bedroom 2	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
TV	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	**All**	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Weekend	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Computer	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hairdryer	**Weekdays**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	**All**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

Zone 8

Zone 8	1. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
Full-time employee	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living room	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bedroom	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
Lighting-Workroom	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
TV	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Laptop	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

Zone 9

Zone 9	1. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
Part-time employee	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living+bed room	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
TV	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Cooker & Oven	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Laptop	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

Zone10

Zone 10	3. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
Full-time employee	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Housewife	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
School-aged child	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living room	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
Lighting-Bedroom 1	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
Lighting-Bedroom 2	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
TV	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Weekend	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Computer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

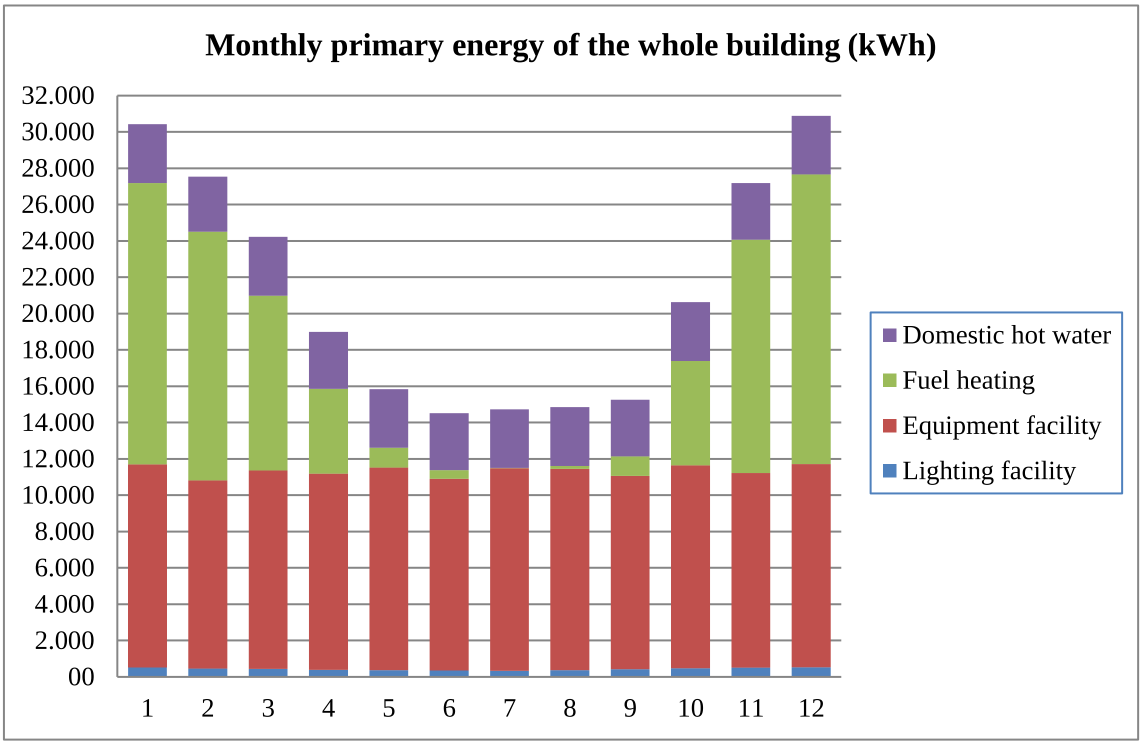
Zone 11

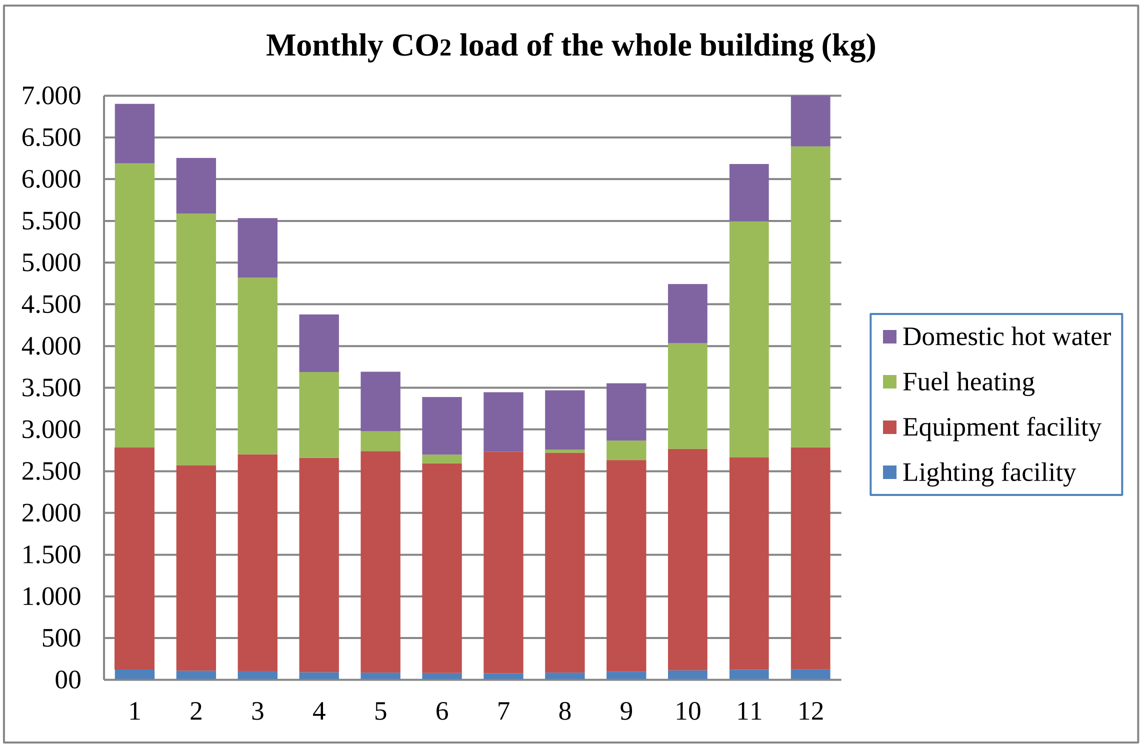
Zone 11	2. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
Full-time worker 1	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Full-time worker 2	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living room	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
Lighting-Bedroom 1	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
Lighting-Bedroom 2	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	1,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0
Lighting-Kitchen	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
TV	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Computer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

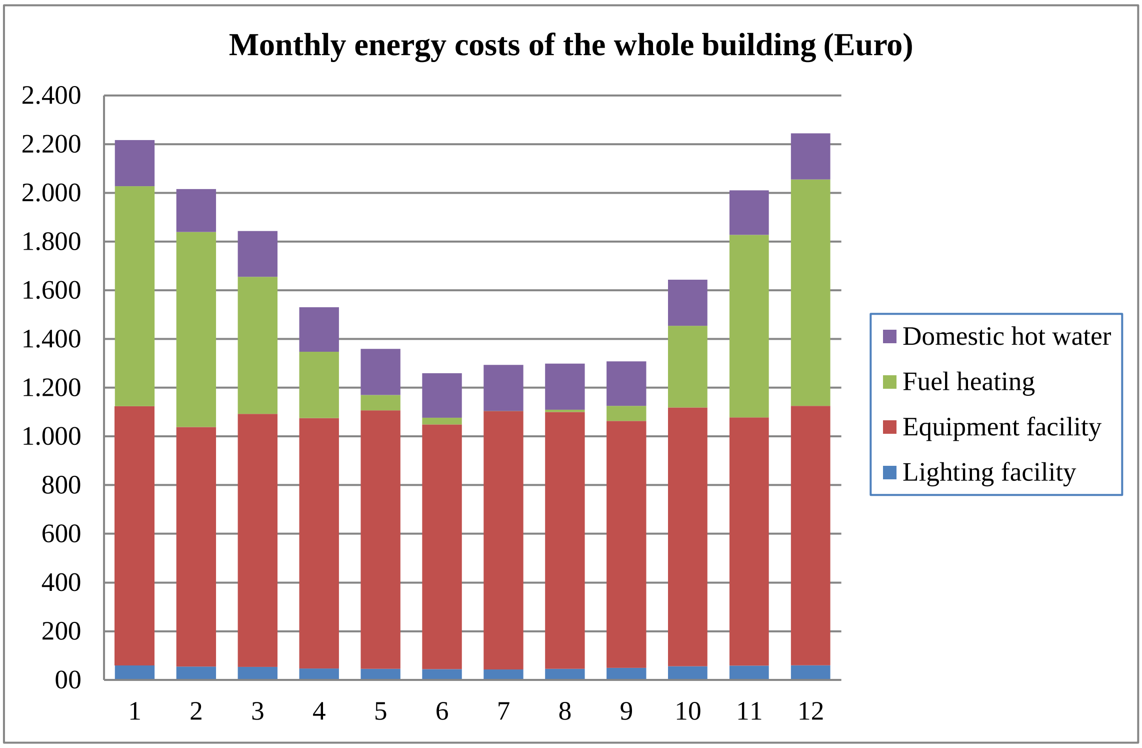
Zone 12

Zone 12	1. per.	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	24:00
University student	Weekdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	Saturdays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0
	Sundays	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Lighting-Living+bed room	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0
Lighting-Kitchen	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting-Bathroom	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0
Refrigerate	All	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Cooker & Oven	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hoover	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Dishwasher	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coffee machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Weekend	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water boiler	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wash machine	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Laptop	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,0	0,0
Hairdryer	Weekdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Saturdays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sundays	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other electrical appliances	All	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0

Appendix 14 Monthly delivered energy, CO_2 load and energy costs of the whole building





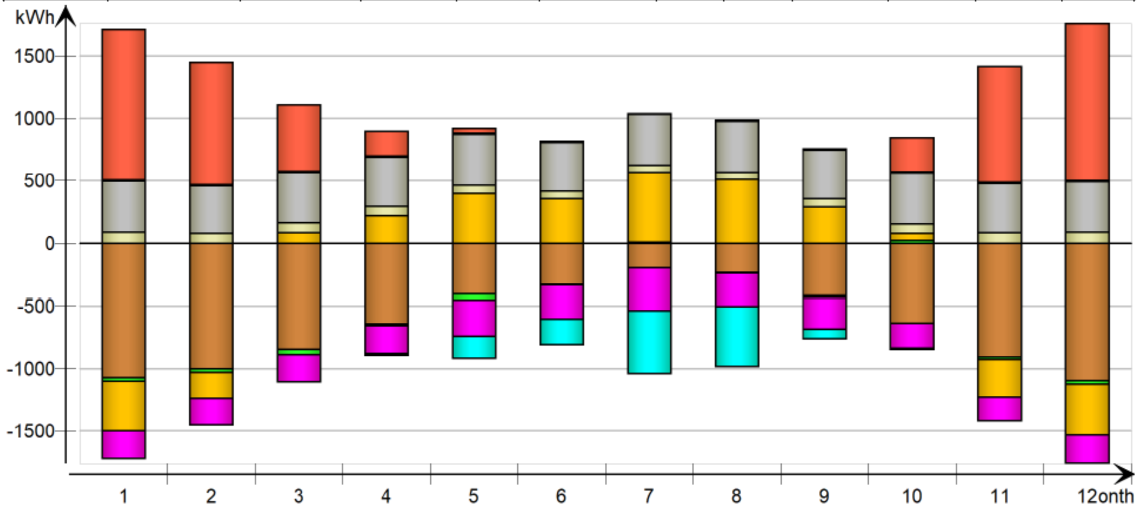

Monthly energy costs of the whole building (Euro)
2.400
2.200
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
00
1
2
3
4
5
6
7
8
9
10
11
12
Domestic hot water
Fuel heating
Equipment facility
Lighting facility

Appendix 15 Energy balance for zones

Zone 1

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-1071.0	-27.2	-397.7	0.0	-220.1	86.6	409.3	10.7	1208.0	-0.0	0.0
2	-1002.0	-28.0	-209.0	0.0	-212.6	79.3	380.6	9.9	980.5	0.0	0.0
3	-848.0	-44.9	85.2	0.0	-214.5	79.9	402.0	9.6	530.6	-2.5	0.0
4	-638.4	-16.6	219.9	0.0	-223.8	72.3	395.4	8.0	195.2	-14.9	0.0
5	-405.3	-49.1	398.3	0.0	-285.3	63.5	409.1	7.2	37.1	-178.0	0.0
6	-328.5	-4.0	354.2	0.0	-270.2	59.5	388.0	6.6	0.7	-209.2	0.0
7	-200.0	10.5	558.1	0.0	-338.3	54.4	408.9	6.2	0.0	-502.0	0.0
8	-237.1	-4.6	509.3	0.0	-262.7	56.3	408.1	7.5	0.0	-479.2	0.0
9	-417.1	-14.7	291.7	0.0	-250.8	64.5	389.0	9.3	1.4	-76.5	0.0
10	-636.2	25.2	55.1	0.0	-203.5	76.6	409.2	10.4	270.3	-10.1	0.0
11	-906.5	-18.7	-303.1	0.0	-188.4	82.6	394.5	10.3	927.4	0.0	0.0
12	-1097.0	-27.4	-411.1	0.0	-225.9	87.5	404.9	10.7	1257.0	0.0	0.0
Total	-7787.1	-199.6	1150.9	0.0	-2896.1	863.0	4799.0	106.5	5408.2	-1472.3	0.0



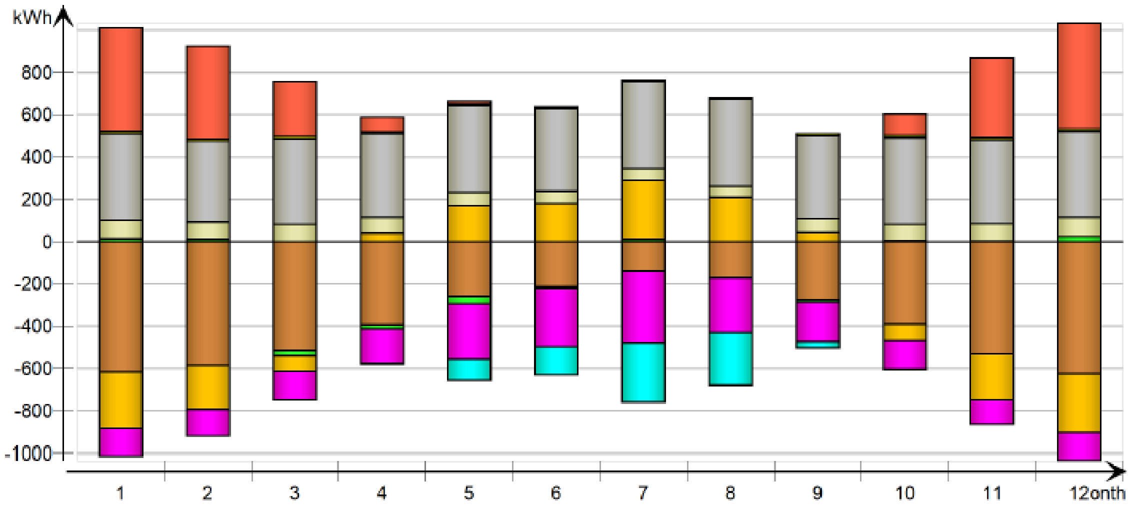
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-976.0	0.0	0.0	-534.6	0.0	-95.1
2	-910.6	0.0	0.0	-518.9	0.0	-91.9
3	-766.0	0.0	0.0	-474.8	0.0	-82.0
4	-573.4	0.0	0.0	-384.5	0.0	-65.1
5	-359.8	0.0	0.0	-283.1	0.0	-45.5
6	-290.6	0.0	0.0	-236.7	0.0	-37.9
7	-171.7	0.0	0.0	-198.6	0.0	-28.2
8	-207.5	0.0	0.0	-205.0	0.0	-29.6
9	-373.9	0.0	0.0	-268.8	0.0	-43.2
10	-575.7	0.0	0.0	-355.2	0.0	-60.5
11	-825.5	0.0	0.0	-454.3	0.0	-81.0
12	-999.8	0.0	0.0	-544.1	0.0	-97.7
Total	-7030.5	0.0	0.0	-4458.6	0.0	-757.7

<u>Zone 2</u>

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-617.2	13.3	-267.9	0.0	-126.9	88.0	409.6	9.6	489.3	0.0	0.0
2	-586.1	10.3	-209.1	0.0	-123.8	81.3	380.8	9.0	435.7	-0.0	0.0
3	-514.9	-24.5	-75.9	0.0	-136.7	81.1	402.3	9.1	257.6	-0.6	0.0
4	-395.2	-20.0	39.6	0.0	-162.9	72.3	395.6	7.8	66.8	-6.9	0.0
5	-260.6	-37.4	170.6	0.0	-262.0	62.2	409.3	7.0	8.9	-100.8	0.0
6	-212.8	-10.3	181.3	0.0	-279.1	56.9	388.2	6.4	0.0	-133.4	0.0
7	-137.1	8.9	279.8	0.0	-341.1	53.5	409.1	6.1	0.0	-281.9	0.0
8	-167.3	-3.8	207.5	0.0	-259.2	55.3	408.4	7.4	0.0	-250.9	0.0
9	-276.0	-11.4	42.3	0.0	-187.4	63.8	389.3	8.7	0.0	-32.4	0.0
10	-391.4	5.2	-76.6	0.0	-134.4	77.2	409.4	9.4	101.1	-3.1	0.0
11	-532.6	2.5	-219.2	0.0	-115.6	82.7	394.7	9.3	376.1	-0.0	0.0
12	-624.9	25.1	-278.1	0.0	-128.7	90.0	405.2	9.6	499.8	-0.0	0.0
Total	-4716.1	-42.2	-205.7	0.0	-2257.8	864.4	4801.9	99.4	2235.3	-809.9	0.0



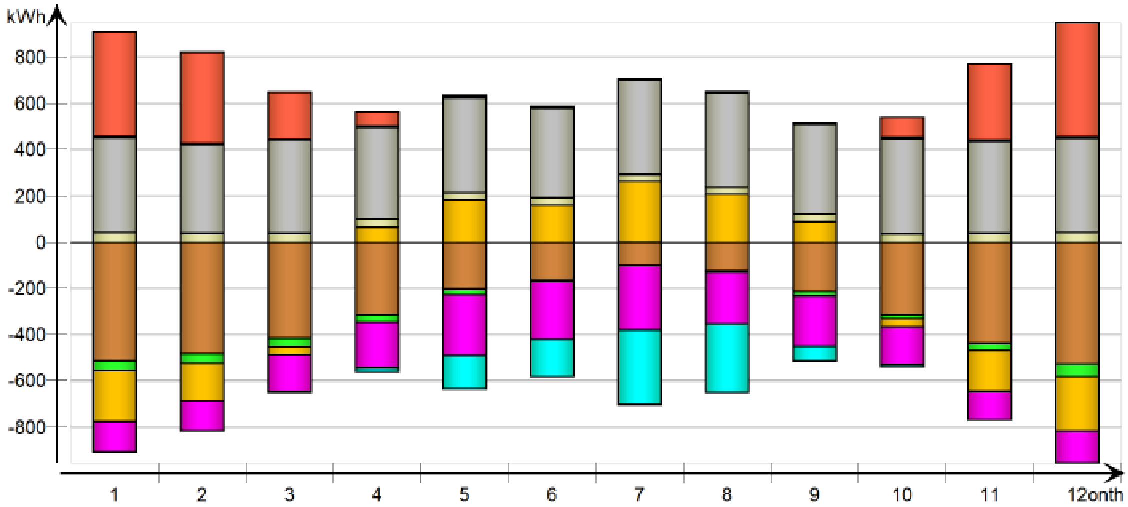
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-562.9	0.0	0.0	-315.3	0.0	-54.3
2	-533.8	0.0	0.0	-305.0	0.0	-52.3
3	-467.3	0.0	0.0	-283.5	0.0	-47.6
4	-356.7	0.0	0.0	-232.9	0.0	-38.5
5	-233.1	0.0	0.0	-174.0	0.0	-27.5
6	-189.2	0.0	0.0	-149.5	0.0	-23.6
7	-119.8	0.0	0.0	-121.5	0.0	-17.3
8	-148.9	0.0	0.0	-126.5	0.0	-18.3
9	-249.9	0.0	0.0	-165.1	0.0	-26.2
10	-355.8	0.0	0.0	-213.5	0.0	-35.5
11	-485.5	0.0	0.0	-272.3	0.0	-47.1
12	-570.0	0.0	0.0	-316.1	0.0	-54.9
Total	-4272.9	0.0	0.0	-2675.2	0.0	-443.2

Zone 3

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-512.0	-43.9	-221.1	0.0	-131.6	42.3	409.3	6.0	449.9	-0.0	0.0
2	-483.8	-40.9	-165.2	0.0	-130.5	39.1	380.6	5.6	394.2	-0.1	0.0
3	-414.3	-37.8	-35.5	0.0	-159.7	39.5	402.0	5.6	201.4	-2.9	0.0
4	-314.8	-32.6	64.9	0.0	-197.2	35.4	395.4	4.9	60.9	-18.5	0.0
5	-201.5	-26.9	184.1	0.0	-263.5	31.0	409.1	4.8	7.0	-145.5	0.0
6	-165.3	-6.7	162.2	0.0	-251.0	28.8	388.0	4.5	0.0	-161.8	0.0
7	-100.1	0.9	262.4	0.0	-282.0	27.1	408.9	4.6	0.0	-322.9	0.0
8	-121.8	-7.7	209.1	0.0	-226.4	28.0	408.1	4.9	0.0	-295.6	0.0
9	-212.3	-20.8	87.2	0.0	-218.2	31.4	389.0	5.4	0.0	-63.4	0.0
10	-313.2	-17.1	-36.2	0.0	-162.8	37.8	409.2	5.9	85.8	-11.0	0.0
11	-436.9	-31.2	-177.3	0.0	-124.0	40.2	394.5	5.8	328.0	-0.3	0.0
12	-525.1	-55.9	-234.6	0.0	-131.6	42.9	404.9	6.0	492.4	-0.1	0.0
Total	-3801.1	-320.5	99.9	0.0	-2278.5	423.6	4799.0	64.1	2019.6	-1022.0	0.0



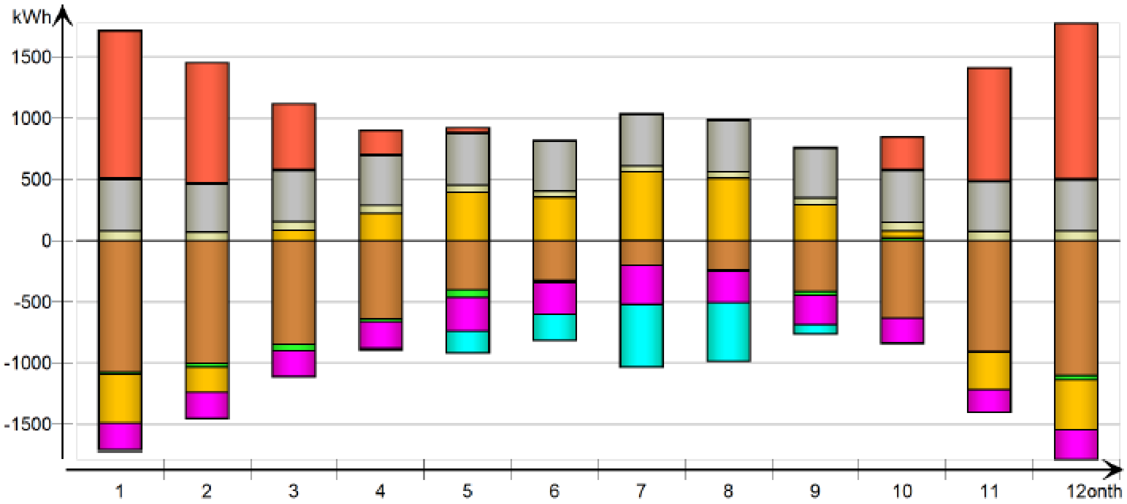
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-465.8	0.0	0.0	-272.5	0.0	-46.1
2	-439.5	0.0	0.0	-264.5	0.0	-44.3
3	-374.8	0.0	0.0	-241.6	0.0	-39.5
4	-283.0	0.0	0.0	-197.8	0.0	-31.8
5	-179.1	0.0	0.0	-147.2	0.0	-22.3
6	-146.5	0.0	0.0	-124.3	0.0	-18.9
7	-86.5	0.0	0.0	-100.6	0.0	-13.6
8	-107.3	0.0	0.0	-104.4	0.0	-14.5
9	-190.8	0.0	0.0	-140.5	0.0	-21.5
10	-283.8	0.0	0.0	-181.8	0.0	-29.4
11	-397.4	0.0	0.0	-234.1	0.0	-39.5
12	-477.8	0.0	0.0	-278.4	0.0	-47.3
Total	-3432.3	0.0	0.0	-2287.7	0.0	-368.7

Zone 4

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-1073.0	-17.9	-398.8	0.0	-220.1	77.8	418.8	10.7	1201.0	0.0	0.0
2	-1003.0	-27.1	-209.5	0.0	-212.4	71.1	390.1	9.9	979.4	0.0	0.0
3	-846.8	-55.0	85.7	0.0	-211.3	72.0	414.0	9.6	532.0	-2.6	0.0
4	-637.4	-23.2	220.5	0.0	-217.3	65.3	404.9	7.8	191.4	-14.9	0.0
5	-404.6	-63.9	398.8	0.0	-274.0	56.9	418.7	7.0	36.8	-178.2	0.0
6	-328.1	-14.9	354.6	0.0	-262.3	53.2	400.0	6.5	0.8	-212.4	0.0
7	-200.4	4.0	558.2	0.0	-323.5	48.2	418.5	6.1	0.0	-513.3	0.0
8	-237.0	-15.1	509.5	0.0	-257.4	49.8	417.7	7.3	0.0	-477.3	0.0
9	-415.5	-29.4	292.5	0.0	-242.4	58.1	400.9	9.2	1.5	-78.1	0.0
10	-635.0	23.8	55.6	0.0	-198.6	68.9	418.7	10.3	264.0	-10.6	0.0
11	-906.8	-10.1	-303.3	0.0	-188.0	74.0	404.0	10.3	918.3	0.0	0.0
12	-1102.0	-33.1	-413.5	0.0	-226.7	79.7	416.6	10.7	1267.0	0.0	0.0
Total	-7789.6	-262.0	1150.3	0.0	-2834.0	775.0	4922.9	105.5	5392.2	-1487.3	0.0



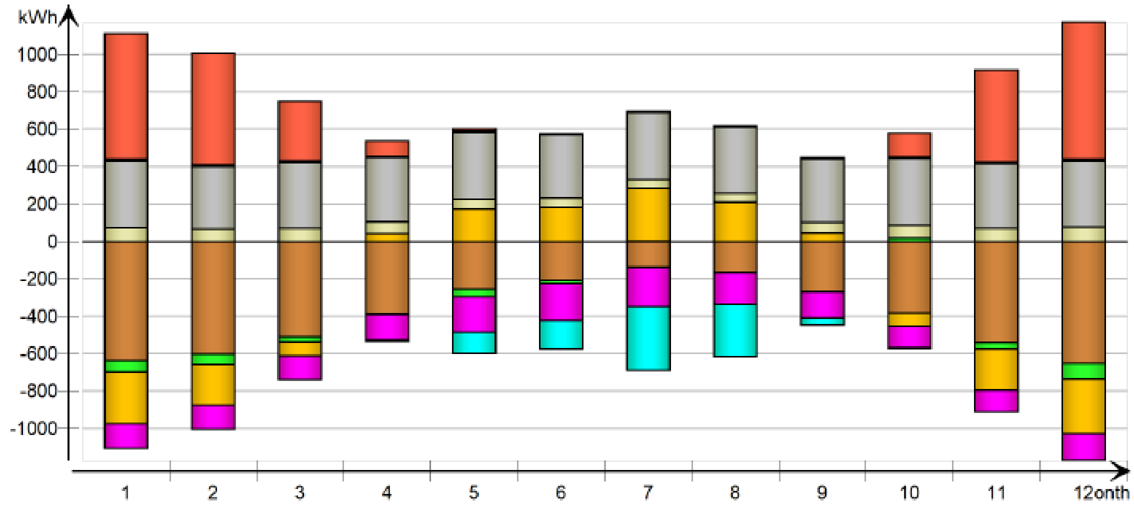
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-977.8	0.0	0.0	-535.5	0.0	-95.3
2	-911.1	0.0	0.0	-519.2	0.0	-92.0
3	-764.8	0.0	0.0	-474.1	0.0	-82.0
4	-572.3	0.0	0.0	-383.9	0.0	-65.1
5	-359.1	0.0	0.0	-282.6	0.0	-45.5
6	-290.2	0.0	0.0	-236.3	0.0	-37.9
7	-172.1	0.0	0.0	-198.5	0.0	-28.2
8	-207.4	0.0	0.0	-204.8	0.0	-29.7
9	-372.3	0.0	0.0	-267.9	0.0	-43.2
10	-574.5	0.0	0.0	-354.5	0.0	-60.5
11	-825.8	0.0	0.0	-454.4	0.0	-81.0
12	-1004.0	0.0	0.0	-546.4	0.0	-98.2
Total	-7031.4	0.0	0.0	-4458.1	0.0	-758.6

Zone 5

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-636.8	-63.7	-277.9	0.0	-130.8	73.2	355.6	7.7	671.3	-0.0	0.0
2	-602.4	-56.1	-217.6	0.0	-126.8	67.5	330.5	7.2	596.1	-0.0	0.0
3	-510.9	-28.4	-74.2	0.0	-128.3	69.3	349.0	7.5	314.8	-0.9	0.0
4	-387.0	-6.6	43.6	0.0	-135.3	62.0	343.5	6.6	80.2	-9.6	0.0
5	-256.3	-40.7	173.0	0.0	-189.2	52.2	355.5	6.4	12.3	-115.8	0.0
6	-209.0	-15.9	183.5	0.0	-199.5	47.6	336.9	6.2	0.0	-152.6	0.0
7	-135.9	3.4	280.9	0.0	-212.8	44.3	355.5	5.9	0.0	-343.7	0.0
8	-164.0	-5.5	209.4	0.0	-169.6	45.7	354.6	6.6	0.0	-279.9	0.0
9	-268.2	-2.8	46.2	0.0	-139.4	54.4	337.8	7.0	0.0	-38.1	0.0
10	-383.3	17.6	-72.7	0.0	-115.4	66.1	355.5	7.6	126.7	-4.8	0.0
11	-539.6	-34.4	-222.7	0.0	-115.0	69.4	342.6	7.5	490.6	-0.0	0.0
12	-653.6	-83.6	-293.2	0.0	-134.7	75.8	351.6	7.3	728.9	-0.0	0.0
Total	-4747.0	-316.8	-221.6	0.0	-1796.8	727.5	4168.6	83.4	3020.8	-945.5	0.0



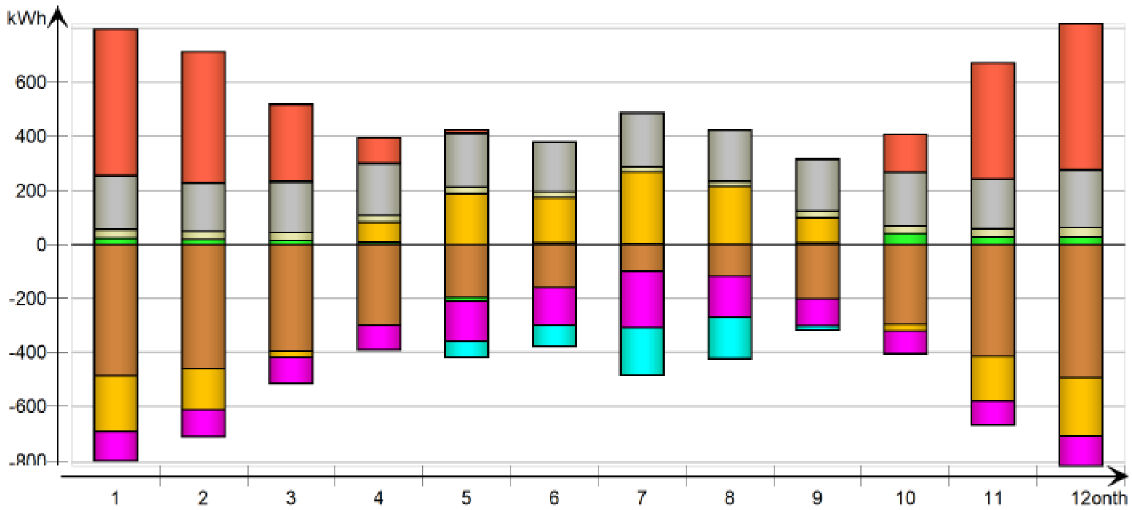
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-580.6	0.0	0.0	-325.4	0.0	-56.1
2	-548.5	0.0	0.0	-313.3	0.0	-53.9
3	-463.7	0.0	0.0	-281.5	0.0	-47.2
4	-349.3	0.0	0.0	-228.7	0.0	-37.7
5	-229.2	0.0	0.0	-171.7	0.0	-27.1
6	-185.8	0.0	0.0	-147.3	0.0	-23.2
7	-119.0	0.0	0.0	-120.4	0.0	-16.9
8	-146.2	0.0	0.0	-124.4	0.0	-17.8
9	-242.7	0.0	0.0	-161.1	0.0	-25.5
10	-348.6	0.0	0.0	-209.5	0.0	-34.7
11	-491.9	0.0	0.0	-275.8	0.0	-47.7
12	-595.9	0.0	0.0	-331.1	0.0	-57.7
Total	-4301.4	0.0	0.0	-2690.2	0.0	-445.5

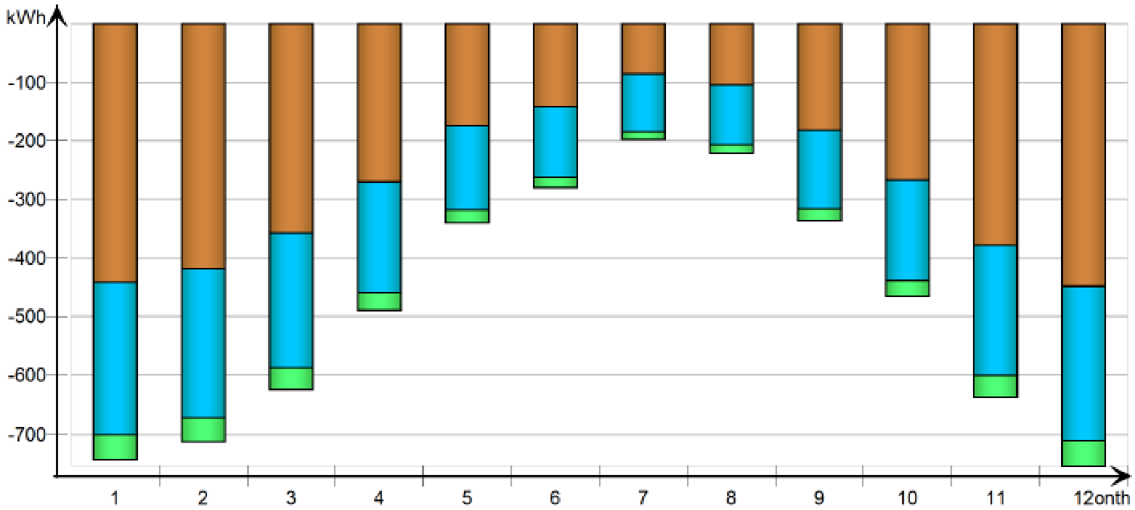
Zone 6

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-485.2	23.3	-206.9	0.0	-102.1	31.6	196.5	2.1	539.7	-0.0	0.0
2	-460.1	18.4	-152.6	0.0	-99.1	29.0	177.5	2.0	484.2	-0.0	0.0
3	-394.7	14.0	-24.9	0.0	-95.9	29.1	186.3	2.1	283.5	-0.4	0.0
4	-300.6	7.8	72.8	0.0	-91.5	26.5	191.4	2.0	91.9	-1.1	0.0
5	-196.0	-16.3	187.6	0.0	-147.5	22.4	196.4	2.0	11.7	-61.3	0.0
6	-159.4	7.1	165.8	0.0	-140.4	20.6	181.2	1.9	0.0	-77.8	0.0
7	-98.3	4.5	263.7	0.0	-211.1	19.1	196.4	1.9	0.0	-177.2	0.0
8	-118.0	1.2	211.5	0.0	-151.5	19.6	187.6	2.1	0.0	-153.5	0.0
9	-202.3	5.8	93.0	0.0	-99.2	23.3	190.1	2.0	1.0	-15.0	0.0
10	-294.5	40.6	-26.2	0.0	-83.5	27.9	196.4	2.1	137.9	-1.9	0.0
11	-415.2	27.6	-165.8	0.0	-89.4	29.3	182.6	2.1	428.0	-0.0	0.0
12	-492.1	27.2	-216.7	0.0	-105.0	33.9	212.8	2.1	537.0	-0.0	0.0
Total	-3616.4	161.0	201.3	0.0	-1416.2	312.2	2295.2	24.6	2514.9	-488.2	0.0



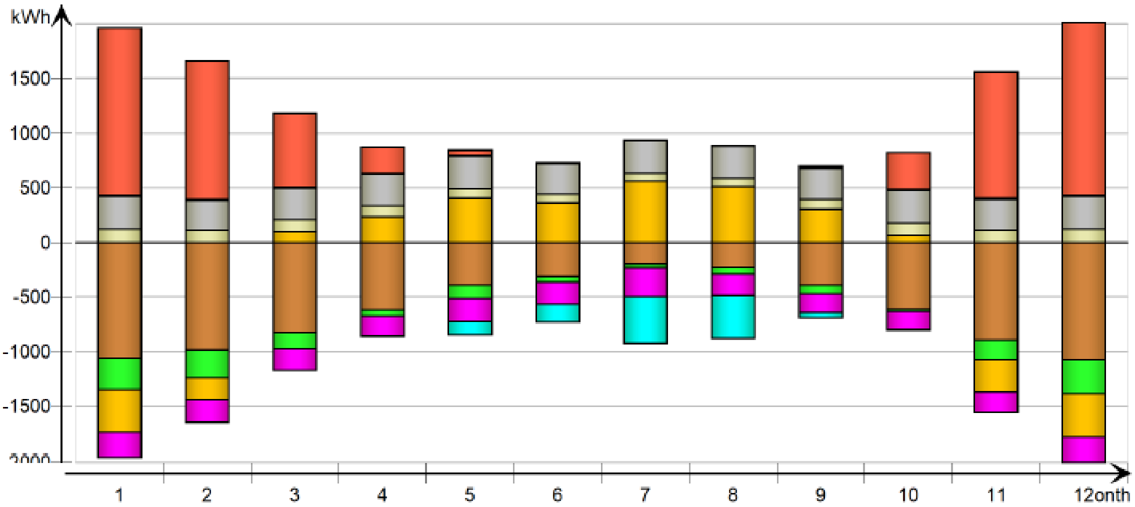
Envelope transmission (kWh)



Zone 7

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu-pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-1058.0	-288.5	-391.5	0.0	-218.3	119.2	296.0	7.9	1530.0	0.0	0.0
2	-986.5	-260.0	-201.5	0.0	-210.3	109.2	273.7	7.4	1265.0	0.0	0.0
3	-826.6	-149.1	95.5	0.0	-198.2	110.3	288.8	7.3	670.2	-1.6	0.0
4	-614.9	-59.1	231.5	0.0	-183.6	99.9	286.5	6.1	239.1	-9.1	0.0
5	-389.7	-122.3	406.1	0.0	-208.1	85.5	295.9	5.6	46.0	-122.6	0.0
6	-311.9	-52.5	362.4	0.0	-207.0	80.0	279.1	5.1	1.6	-160.6	0.0
7	-198.9	-35.8	558.7	0.0	-270.1	70.4	295.9	4.9	0.0	-428.8	0.0
8	-228.7	-65.4	513.5	0.0	-201.7	73.8	292.6	5.8	-0.0	-393.6	0.0
9	-391.9	-79.0	304.0	0.0	-174.2	88.7	282.3	6.8	7.0	-47.9	0.0
10	-613.8	-25.2	65.9	0.0	-167.7	105.2	296.0	7.7	334.1	-5.9	0.0
11	-895.5	-181.9	-298.0	0.0	-186.3	112.8	283.4	7.7	1155.0	0.0	0.0
12	-1074.0	-311.1	-399.9	0.0	-222.2	123.3	298.5	7.5	1575.0	0.0	0.0
Total	-7590.4	-1629.9	1246.7	0.0	-2447.7	1178.3	3468.7	79.8	6822.9	-1170.0	0.0



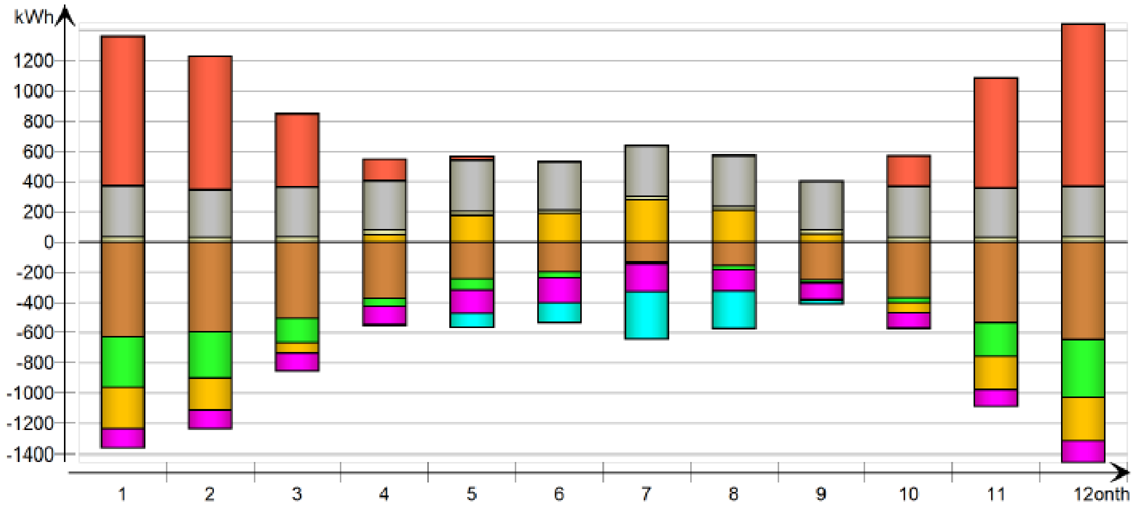
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-963.9	0.0	0.0	-528.3	0.0	-94.2
2	-895.8	0.0	0.0	-511.2	0.0	-90.8
3	-746.6	0.0	0.0	-464.4	0.0	-80.0
4	-552.1	0.0	0.0	-372.9	0.0	-62.8
5	-345.5	0.0	0.0	-275.3	0.0	-44.2
6	-275.5	0.0	0.0	-228.6	0.0	-36.4
7	-170.8	0.0	0.0	-198.0	0.0	-28.1
8	-199.8	0.0	0.0	-200.9	0.0	-28.9
9	-350.8	0.0	0.0	-256.5	0.0	-41.1
10	-555.4	0.0	0.0	-344.3	0.0	-58.4
11	-815.5	0.0	0.0	-449.0	0.0	-80.0
12	-978.6	0.0	0.0	-532.8	0.0	-95.9
Total	-6850.3	0.0	0.0	-4362.2	0.0	-740.8

Zone 8

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-627.3	-335.4	-273.1	0.0	-128.8	34.6	335.4	5.6	988.5	-0.0	0.0
2	-593.0	-305.1	-212.8	0.0	-123.6	31.9	311.5	5.3	885.4	-0.0	0.0
3	-500.3	-161.4	-68.8	0.0	-118.3	32.8	328.9	5.3	481.3	-0.5	0.0
4	-373.2	-48.5	50.7	0.0	-119.6	29.8	324.0	4.6	137.1	-6.4	0.0
5	-244.3	-74.8	179.1	0.0	-156.0	25.3	335.3	4.3	22.8	-93.1	0.0
6	-197.4	-39.2	189.5	0.0	-167.5	23.1	317.5	4.0	0.0	-131.6	0.0
7	-132.3	-10.8	282.7	0.0	-187.0	21.0	335.2	3.8	-0.0	-313.9	0.0
8	-156.3	-28.6	213.4	0.0	-144.8	21.9	334.0	4.4	-0.0	-245.4	0.0
9	-249.4	-21.0	55.7	0.0	-112.6	26.9	318.8	4.9	1.4	-26.6	0.0
10	-370.2	-32.3	-66.0	0.0	-102.0	31.6	335.3	5.5	199.4	-2.8	0.0
11	-531.6	-224.8	-218.6	0.0	-110.8	32.6	322.8	5.5	724.2	-0.0	0.0
12	-644.1	-383.3	-288.2	0.0	-132.5	36.2	332.6	5.2	1074.0	0.0	0.0
Total	-4619.4	-1665.3	-156.4	0.0	-1603.5	347.6	3931.3	58.3	4514.1	-820.2	0.0



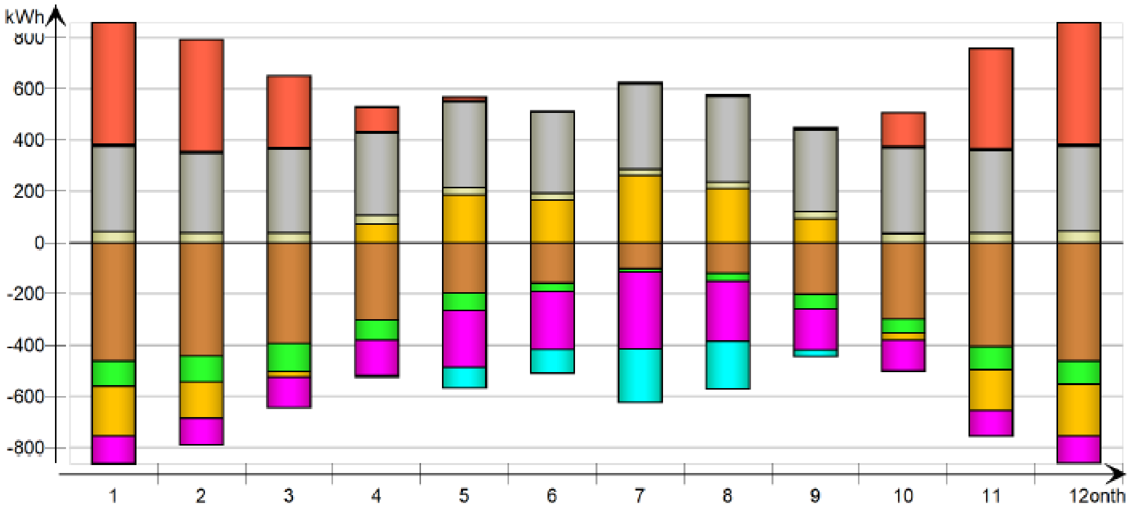
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-571.5	0.0	0.0	-320.5	0.0	-55.8
2	-539.5	0.0	0.0	-308.5	0.0	-53.5
3	-453.7	0.0	0.0	-276.2	0.0	-46.6
4	-336.6	0.0	0.0	-221.7	0.0	-36.6
5	-218.2	0.0	0.0	-165.5	0.0	-26.2
6	-175.2	0.0	0.0	-141.4	0.0	-22.2
7	-115.7	0.0	0.0	-118.6	0.0	-16.6
8	-139.1	0.0	0.0	-120.4	0.0	-17.2
9	-225.5	0.0	0.0	-151.6	0.0	-23.9
10	-336.5	0.0	0.0	-202.8	0.0	-33.7
11	-484.2	0.0	0.0	-271.7	0.0	-47.4
12	-586.7	0.0	0.0	-326.2	0.0	-57.4
Total	-4182.4	0.0	0.0	-2625.1	0.0	-437.1

Zone 9

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-461.2	-97.6	-193.7	0.0	-103.6	42.7	333.0	6.0	473.2	0.0	0.0
2	-440.8	-103.4	-142.0	0.0	-103.0	39.1	309.1	5.7	434.3	-0.0	0.0
3	-393.6	-110.6	-24.2	0.0	-119.2	38.0	325.9	5.7	277.5	-0.8	0.0
4	-302.7	-79.3	71.5	0.0	-139.2	33.4	321.6	5.1	94.4	-6.5	0.0
5	-196.4	-68.5	187.1	0.0	-222.8	28.2	332.9	5.1	12.3	-79.4	0.0
6	-158.9	-32.9	165.7	0.0	-226.6	26.2	314.5	4.8	0.0	-94.3	0.0
7	-99.9	-15.2	262.6	0.0	-299.4	23.9	332.8	4.9	0.0	-211.3	0.0
8	-118.7	-32.3	210.7	0.0	-234.4	25.0	331.6	5.2	0.0	-188.5	0.0
9	-201.5	-58.5	93.1	0.0	-161.2	29.3	315.8	5.3	1.8	-25.9	0.0
10	-297.9	-55.2	-28.1	0.0	-120.8	35.7	332.9	6.0	129.3	-3.5	0.0
11	-405.4	-91.7	-160.5	0.0	-99.6	39.2	320.4	5.9	390.5	-0.1	0.0
12	-462.1	-92.0	-200.4	0.0	-101.4	44.5	329.6	5.7	475.0	-0.0	0.0
Total	-3539.1	-837.1	241.9	0.0	-1931.2	405.2	3900.1	65.3	2288.3	-610.2	0.0



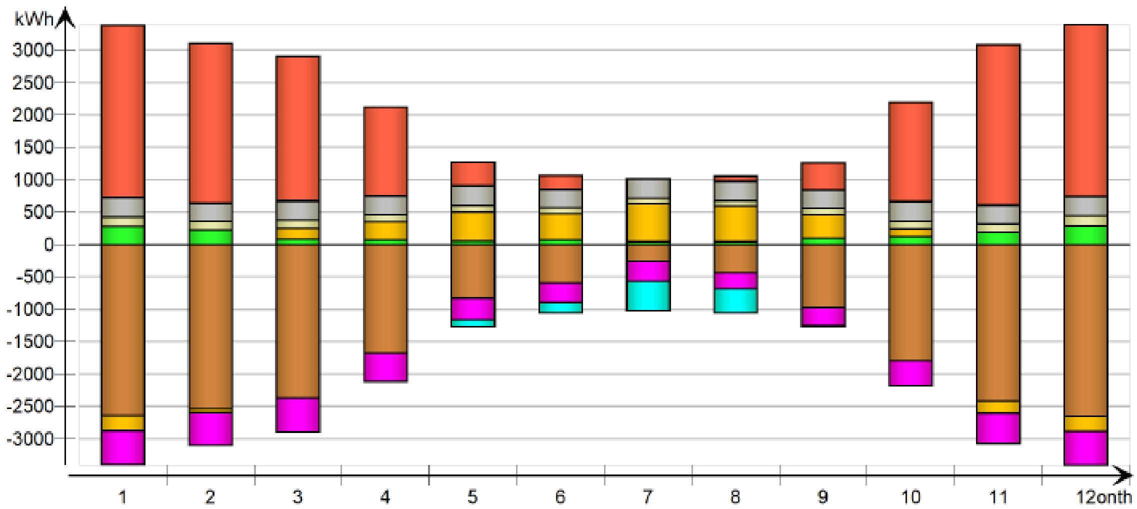
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-419.7	0.0	0.0	-245.2	0.0	-41.5
2	-400.4	0.0	0.0	-241.3	0.0	-40.4
3	-355.8	0.0	0.0	-230.3	0.0	-37.8
4	-271.8	0.0	0.0	-191.2	0.0	-30.8
5	-174.5	0.0	0.0	-144.2	0.0	-21.9
6	-140.6	0.0	0.0	-120.7	0.0	-18.3
7	-86.3	0.0	0.0	-100.4	0.0	-13.6
8	-104.5	0.0	0.0	-102.8	0.0	-14.3
9	-180.8	0.0	0.0	-134.5	0.0	-20.6
10	-269.8	0.0	0.0	-173.7	0.0	-28.1
11	-368.7	0.0	0.0	-217.3	0.0	-36.7
12	-420.6	0.0	0.0	-244.3	0.0	-41.5
Total	-3193.4	0.0	0.0	-2145.9	0.0	-345.7

Zone 10

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu-pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-2639.0	277.8	-234.6	0.0	-500.5	144.3	296.0	7.9	2646.0	0.0	0.0
2	-2537.0	225.8	-62.8	0.0	-503.4	131.3	273.7	7.4	2463.0	0.0	0.0
3	-2371.0	75.9	170.4	0.0	-522.3	122.4	288.8	7.4	2226.0	-0.1	0.0
4	-1677.0	73.8	279.5	0.0	-438.7	108.4	286.5	6.2	1362.0	-3.6	0.0
5	-826.9	52.0	454.0	0.0	-331.5	95.8	295.9	5.7	357.4	-105.6	0.0
6	-595.5	66.9	400.9	0.0	-294.3	88.4	279.1	5.3	206.6	-160.9	0.0
7	-252.2	44.5	587.4	0.0	-314.5	76.1	295.9	5.0	1.6	-447.7	0.0
8	-436.1	48.3	551.1	0.0	-249.4	82.0	292.6	6.0	75.1	-373.0	0.0
9	-972.0	102.5	357.2	0.0	-276.7	100.8	282.3	6.9	415.3	-20.0	0.0
10	-1796.0	124.3	118.2	0.0	-390.5	115.0	296.0	7.7	1522.0	-0.1	0.0
11	-2420.0	188.3	-193.6	0.0	-468.1	129.2	283.4	7.7	2470.0	0.0	0.0
12	-2650.0	283.4	-232.6	0.0	-498.3	150.5	298.5	7.5	2639.0	0.0	0.0
Total	-19172.7	1563.5	2195.1	0.0	-4788.2	1344.2	3468.7	80.5	16384.0	-1111.0	0.0



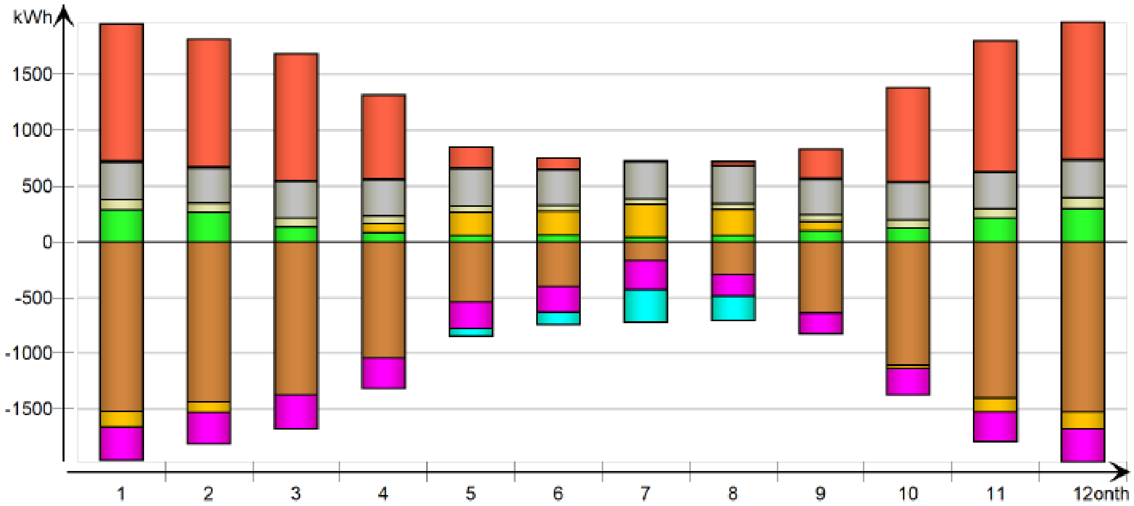
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-679.7	-1742.0	0.0	-372.8	0.0	-217.3
2	-646.5	-1672.0	0.0	-375.6	0.0	-218.7
3	-616.8	-1528.0	0.0	-395.2	0.0	-226.0
4	-473.2	-1018.0	0.0	-331.5	0.0	-185.7
5	-268.8	-436.0	0.0	-235.0	0.0	-122.1
6	-215.0	-279.9	0.0	-196.8	0.0	-100.6
7	-131.9	-41.3	0.0	-177.7	0.0	-79.0
8	-143.7	-214.7	0.0	-171.0	0.0	-77.7
9	-259.3	-603.2	0.0	-209.3	0.0	-109.5
10	-463.0	-1166.0	0.0	-296.2	0.0	-167.0
11	-624.9	-1592.0	0.0	-346.3	0.0	-202.8
12	-675.7	-1758.0	0.0	-366.9	0.0	-216.4
Total	-5198.5	-12051.1	0.0	-3474.3	0.0	-1922.9

<u>Zone 11</u>

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-1518.0	288.0	-143.7	0.0	-283.7	91.6	333.3	7.3	1224.0	0.0	0.0
2	-1434.0	262.6	-94.1	0.0	-280.4	84.3	309.5	6.9	1144.0	0.0	0.0
3	-1375.0	133.0	-0.5	0.0	-303.7	78.7	326.8	7.0	1133.0	-0.0	0.0
4	-1040.0	84.0	85.0	0.0	-277.8	67.4	322.1	6.2	752.4	-1.3	0.0
5	-538.7	56.3	206.1	0.0	-238.7	57.8	333.3	5.9	184.7	-68.9	0.0
6	-402.5	60.5	212.0	0.0	-232.9	52.6	315.6	5.7	97.7	-111.1	0.0
7	-168.3	42.0	295.3	0.0	-260.3	45.6	333.2	5.4	0.1	-295.7	0.0
8	-293.0	54.0	232.2	0.0	-193.0	49.3	331.8	6.1	33.2	-222.7	0.0
9	-639.3	100.4	84.7	0.0	-183.3	61.5	317.0	6.6	258.4	-8.5	0.0
10	-1108.0	122.8	-27.7	0.0	-241.2	71.4	333.3	7.2	839.9	-0.0	0.0
11	-1399.0	214.3	-125.8	0.0	-267.6	81.7	320.7	7.2	1167.0	0.0	0.0
12	-1526.0	297.4	-149.7	0.0	-281.6	97.1	330.9	6.9	1223.0	0.0	0.0
Total	-11441.8	1715.4	573.8	0.0	-3044.2	838.9	3907.5	78.5	8057.4	-708.2	0.0



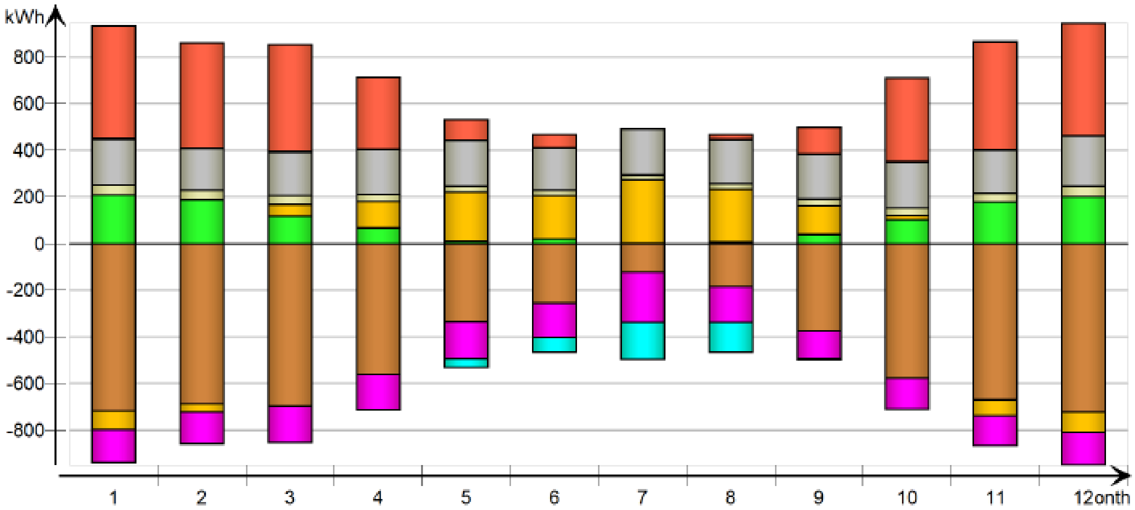
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-342.8	-1052.0	0.0	-191.4	0.0	-123.2
2	-329.7	-982.1	0.0	-190.3	0.0	-121.8
3	-333.8	-910.0	0.0	-208.6	0.0	-131.5
4	-276.6	-646.0	0.0	-188.4	0.0	-117.4
5	-172.0	-284.9	0.0	-139.8	0.0	-81.8
6	-136.7	-196.1	0.0	-120.1	0.0	-69.7
7	-95.7	-17.8	0.0	-107.5	0.0	-54.8
8	-107.8	-131.8	0.0	-102.9	0.0	-53.4
9	-173.4	-393.6	0.0	-123.3	0.0	-72.2
10	-267.0	-737.9	0.0	-165.0	0.0	-103.1
11	-318.0	-965.4	0.0	-179.1	0.0	-116.0
12	-341.5	-1062.0	0.0	-187.7	0.0	-122.3
Total	-2895.0	-7379.6	0.0	-1904.1	0.0	-1167.3

Zone 12

Energy balance (kWh)

Month	Envelope & Thermal bridges	Internal Walls and Masses	Window & Solar	Mech. supply air	Infiltra-tion & Openings	Occu pants	Equip ment	Lighting	Local heating units	Local cooling units	Net losses
1	-718.7	209.4	-81.4	0.0	-133.9	42.7	196.5	2.1	482.5	0.0	0.0
2	-688.3	189.6	-35.9	0.0	-135.1	39.1	177.5	2.0	450.6	0.0	0.0
3	-696.5	119.0	49.5	0.0	-156.0	36.3	186.3	2.1	458.8	-0.0	0.0
4	-561.8	67.3	114.0	0.0	-151.6	30.9	191.4	2.0	306.9	-0.0	0.0
5	-335.0	8.7	212.3	0.0	-157.7	25.7	196.4	2.1	84.7	-38.0	0.0
6	-254.2	19.4	185.0	0.0	-148.5	23.2	181.2	1.9	54.7	-63.9	0.0
7	-120.4	2.7	272.1	0.0	-215.9	20.4	196.4	2.0	0.4	-158.9	0.0
8	-184.8	7.6	226.5	0.0	-153.5	21.8	187.6	2.1	19.4	-127.8	0.0
9	-375.2	40.5	123.5	0.0	-118.9	27.1	190.1	2.0	113.9	-4.2	0.0
10	-577.3	103.5	18.1	0.0	-132.8	32.4	196.4	2.1	356.5	-0.2	0.0
11	-669.0	179.6	-69.3	0.0	-127.6	37.8	182.6	2.1	463.1	0.0	0.0
12	-723.8	201.6	-86.8	0.0	-133.4	45.9	212.8	2.1	481.0	0.0	0.0
Total	-5905.0	1148.8	927.5	0.0	-1764.9	383.4	2295.2	24.8	3272.5	-393.1	0.0



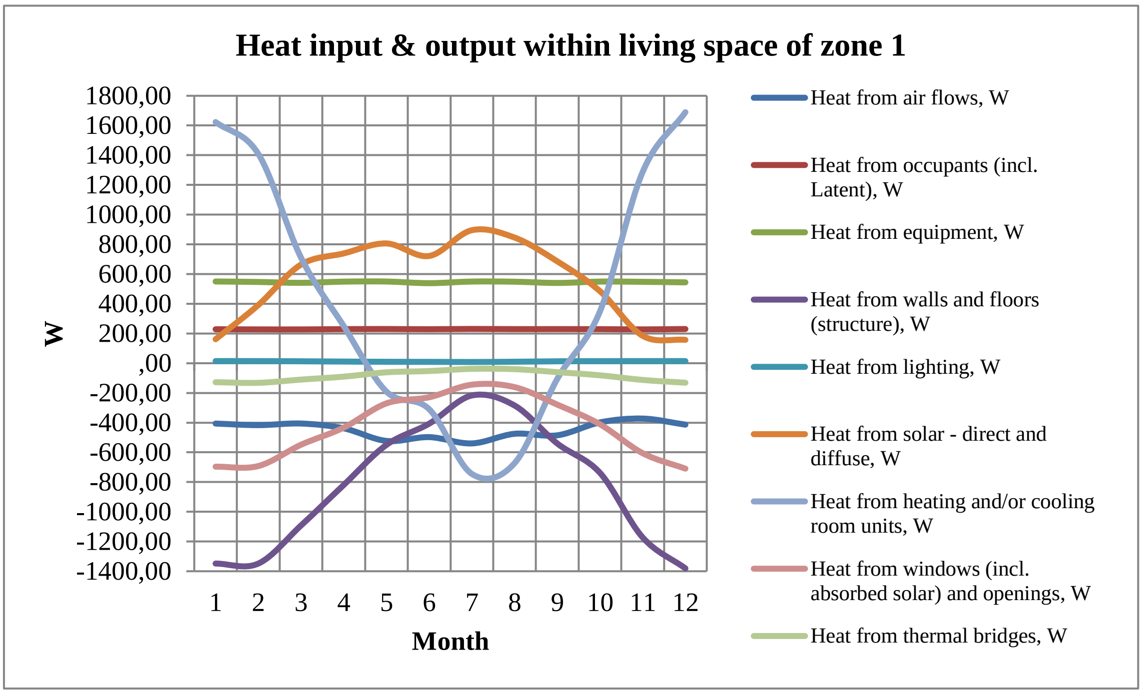
Envelope transmission (kWh)

Month	Walls	Roof	Floor	Windows	Doors	Thermal bridges
1	-225.8	-435.0	0.0	-133.0	0.0	-58.0
2	-218.9	-410.9	0.0	-135.5	0.0	-58.5
3	-230.5	-399.0	0.0	-157.1	0.0	-67.0
4	-199.2	-299.2	0.0	-149.1	0.0	-63.4
5	-133.0	-154.0	0.0	-119.5	0.0	-47.9
6	-108.7	-104.9	0.0	-101.8	0.0	-40.6
7	-71.8	-16.5	0.0	-91.4	0.0	-32.1
8	-79.5	-74.0	0.0	-87.6	0.0	-31.3
9	-128.8	-204.4	0.0	-104.6	0.0	-42.1
10	-188.8	-334.4	0.0	-127.8	0.0	-54.1
11	-211.3	-402.6	0.0	-126.2	0.0	-55.1
12	-225.3	-440.8	0.0	-130.8	0.0	-57.7
Total	-2021.5	-3275.7	0.0	-1464.4	0.0	-607.9

Appendix 16 Heat balance for zones

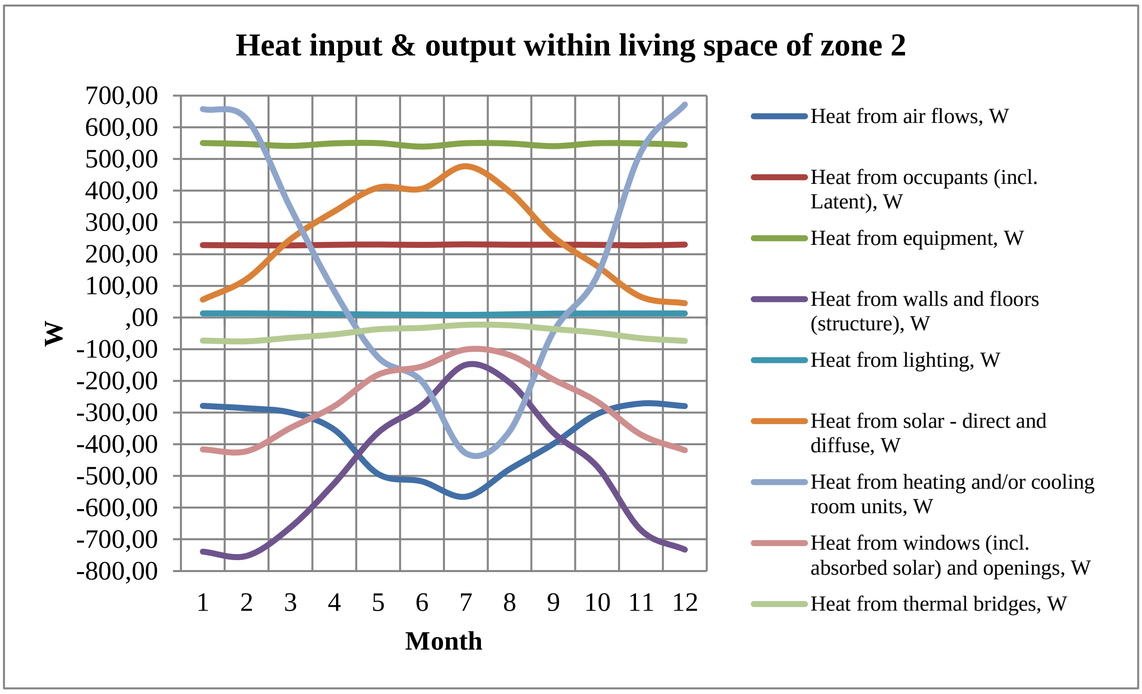
Zone 1

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-406.1	228.5	550.2	-1348.4	14.42	161.5	1623.3	-696.1	-127.8	0.0
February	-416.7	227.7	546.9	-1348.5	14.29	391.6	1408.7	-691.9	-132.0	0.0
March	-405.9	227.5	541.0	-1092.1	12.94	663.9	710.7	-548.5	-110.2	0.0
April	-438.2	229.4	549.1	-819.2	11.12	739.2	250.0	-433.7	-90.35	0.0
May	-522.8	230.1	549.8	-549.6	9.632	806.2	-191.1	-271.2	-61.22	0.0
June	-497.5	228.9	538.9	-409.2	9.173	721.9	-309.4	-229.9	-52.56	0.0
July	-539.7	230.7	549.6	-217.1	8.363	895.4	-745.2	-145.1	-37.9	0.0
August	-474.9	229.5	548.6	-284.6	10.1	845.8	-672.7	-161.7	-39.91	0.0
September	-485.3	229.6	540.3	-540.3	12.92	685.7	-105.3	-280.1	-59.99	0.0
October	-398.3	229.2	549.4	-738.0	13.91	484.7	349.3	-411.4	-81.36	0.0
November	-372.5	227.6	547.9	-1172.6	14.34	184.5	1288.1	-605.4	-112.5	0.0
December	-413.5	230.2	544.3	-1380.7	14.42	157.1	1689.6	-709.6	-131.3	0.0
mean	-447.8	229.1	546.3	-823.1	12.13	562.1	437.8	-431.1	-86.26	0.0
mean*8784.0 h	-3933332.9	2012301.6	4799089.4	-7230120.7	106515.6	4937786.1	3845200.3	-3786878.0	-757678.6	0.0
min	-539.7	227.5	538.9	-1380.7	8.363	157.1	-745.2	-709.6	-132.0	0.0
max	-372.5	230.7	550.2	-217.1	14.42	895.4	1689.6	-145.1	-37.9	0.0



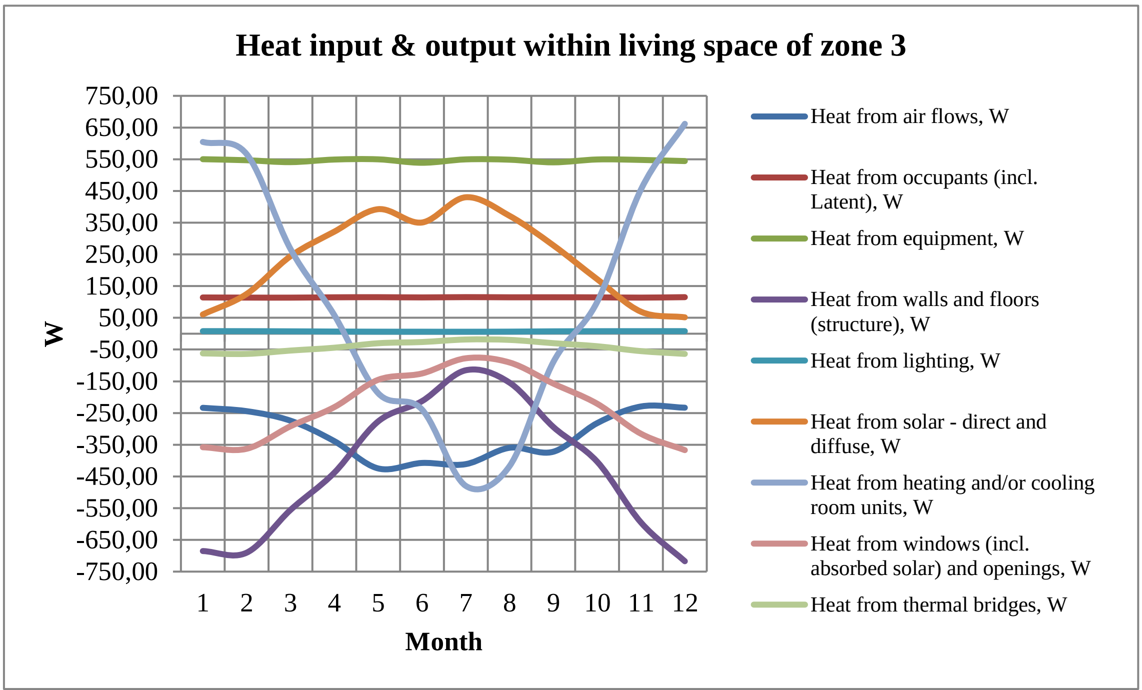
Zone 2

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-278.8	228.4	550.5	-738.7	12.89	56.32	657.6	-416.3	-72.95	0.0
February	-286.4	227.6	547.2	-752.2	12.88	121.5	626.0	-422.0	-75.18	0.0
March	-299.9	227.4	541.3	-662.2	12.19	246.8	346.0	-348.5	-64.03	0.0
April	-353.8	229.4	549.4	-523.3	10.82	334.7	83.27	-279.6	-53.48	0.0
May	-493.6	230.2	550.1	-363.3	9.434	409.7	-125.5	-180.6	-37.05	0.0
June	-517.1	229.1	539.2	-277.1	8.923	406.3	-202.1	-154.5	-32.83	0.0
July	-565.4	230.7	549.9	-149.3	8.241	477.2	-428.2	-100.9	-23.21	0.0
August	-478.7	229.6	548.9	-205.0	9.964	397.1	-358.9	-118.4	-24.66	0.0
September	-398.6	229.7	540.6	-363.2	12.14	254.6	-45.69	-195.6	-36.32	0.0
October	-304.4	229.2	549.7	-470.2	12.64	162.2	131.6	-265.5	-47.79	0.0
November	-271.4	227.6	548.2	-670.8	12.86	65.09	522.3	-369.6	-65.37	0.0
December	-279.5	230.0	544.6	-732.4	12.9	44.96	671.8	-418.8	-73.82	0.0
mean	-377.7	229.1	546.7	-491.2	11.32	248.5	154.7	-271.9	-50.46	0.0
mean*8784.0 h	-3317757.8	2012226.2	4801839.9	-4315094.1	99406.2	2183022.2	1358479.2	-2388777.0	-443246.5	0.0
min	-565.4	227.4	539.2	-752.2	8.241	44.96	-428.2	-422.0	-75.18	0.0
max	-271.4	230.7	550.5	-149.3	12.9	477.2	671.8	-100.9	-23.21	0.0



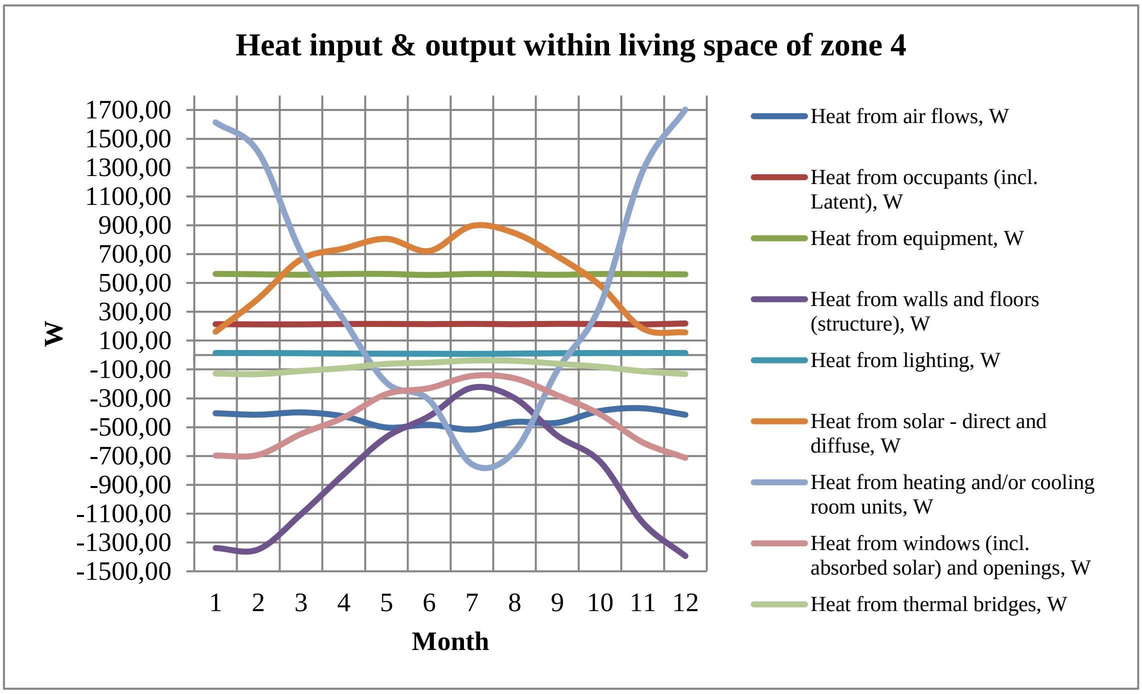
Zone 3

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-233.6	114.3	550.2	-685.2	8.078	60.73	604.7	-357.9	-62.0	0.0
February	-244.2	113.9	546.9	-690.3	8.026	125.3	566.3	-362.7	-63.64	0.0
March	-274.2	113.8	541.0	-555.6	7.547	244.3	267.2	-291.8	-53.15	0.0
April	-338.6	114.8	549.1	-438.3	6.856	321.7	58.83	-231.5	-44.16	0.0
May	-424.7	115.1	549.8	-276.7	6.41	392.6	-187.3	-145.4	-30.05	0.0
June	-407.5	114.5	538.9	-212.7	6.31	350.6	-238.7	-125.4	-26.19	0.0
July	-411.2	115.3	549.6	-115.3	6.222	430.2	-479.7	-77.42	-18.26	0.0
August	-359.6	114.8	548.6	-154.3	6.589	371.6	-417.5	-90.71	-19.46	0.0
September	-372.0	114.9	540.3	-294.1	7.474	278.5	-88.99	-157.3	-29.81	0.0
October	-281.8	114.6	549.4	-403.5	7.906	171.8	100.4	-220.8	-39.54	0.0
November	-229.4	113.9	547.9	-595.3	8.042	69.34	455.2	-315.5	-54.85	0.0
December	-233.2	115.2	544.3	-717.3	8.078	51.66	661.7	-367.0	-63.61	0.0
mean	-317.7	114.6	546.3	-427.2	7.292	239.5	106.7	-228.1	-41.98	0.0
mean*8784.0 h	-2790563.0	1006559.3	4799089.4	-3752887.6	64055.1	2103578.2	936877.7	-2003666.7	-368726.9	0.0
min	-424.7	113.8	538.9	-717.3	6.222	51.66	-479.7	-367.0	-63.64	0.0
max	-229.4	115.3	550.2	-115.3	8.078	430.2	661.7	-77.42	-18.26	0.0



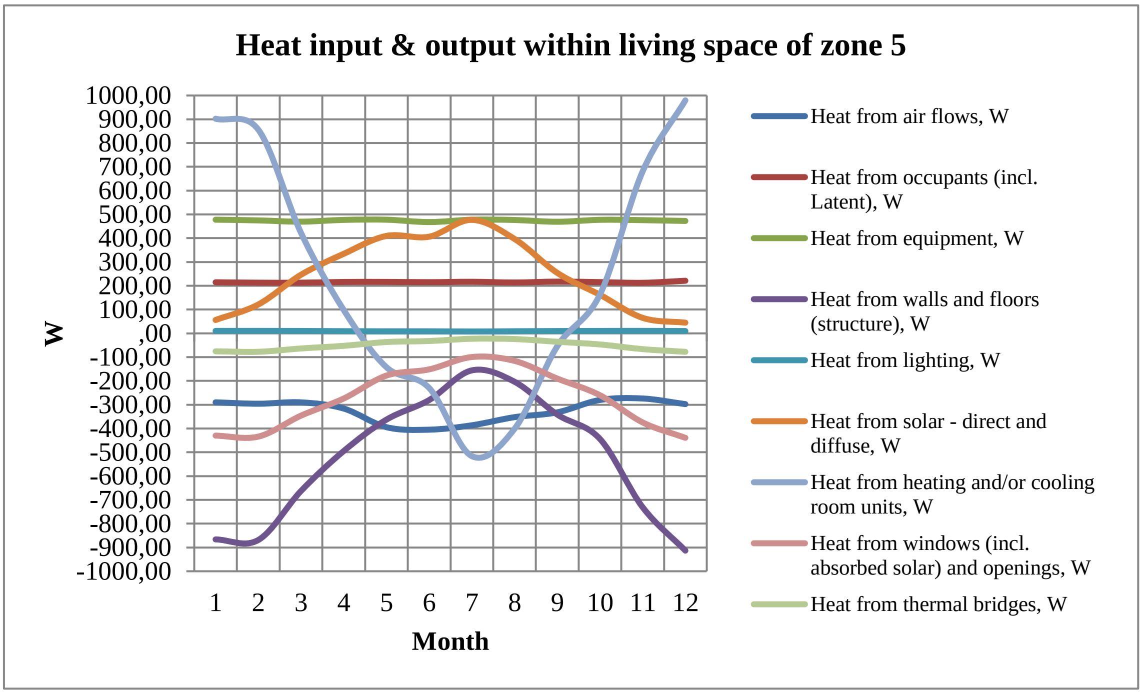
Zone 4

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-403.7	214.3	563.0	-1338.4	14.4	161.4	1614.2	-697.4	-128.1	0.0
February	-413.6	212.9	560.6	-1347.9	14.24	391.3	1407.1	-692.3	-132.2	0.0
March	-397.8	212.9	557.1	-1104.1	12.87	663.7	712.5	-547.6	-110.3	0.0
April	-425.1	215.5	562.3	-826.8	10.9	739.2	244.7	-432.9	-90.41	0.0
May	-502.5	215.8	562.7	-568.5	9.38	806.3	-191.6	-270.5	-61.23	0.0
June	-483.2	214.6	555.5	-424.0	9.016	721.9	-311.9	-229.4	-52.59	0.0
July	-517.1	216.3	562.5	-226.3	8.149	895.5	-757.0	-145.0	-37.9	0.0
August	-463.8	214.0	561.5	-298.5	9.866	845.9	-667.3	-161.4	-39.94	0.0
September	-469.5	216.6	556.8	-558.5	12.76	685.5	-107.4	-278.8	-59.99	0.0
October	-388.0	215.0	562.2	-738.4	13.87	484.3	340.1	-410.5	-81.33	0.0
November	-369.0	212.5	561.2	-1161.0	14.34	184.3	1275.3	-605.6	-112.6	0.0
December	-414.2	219.4	559.9	-1394.1	14.4	156.9	1703.0	-712.7	-131.9	0.0
mean	-437.4	215.0	560.4	-830.3	12.01	562.0	434.9	-431.1	-86.37	0.0
mean*8784.0 h	-3842309.7	1888595.3	4922941.1	-7293531.2	105470.6	4936819.6	3820418.4	-3786424.3	-758638.9	0.0
min	-517.1	212.5	555.5	-1394.1	8.149	156.9	-757.0	-712.7	-132.2	0.0
max	-369.0	219.4	563.0	-226.3	14.4	895.5	1703.0	-145.0	-37.9	0.0



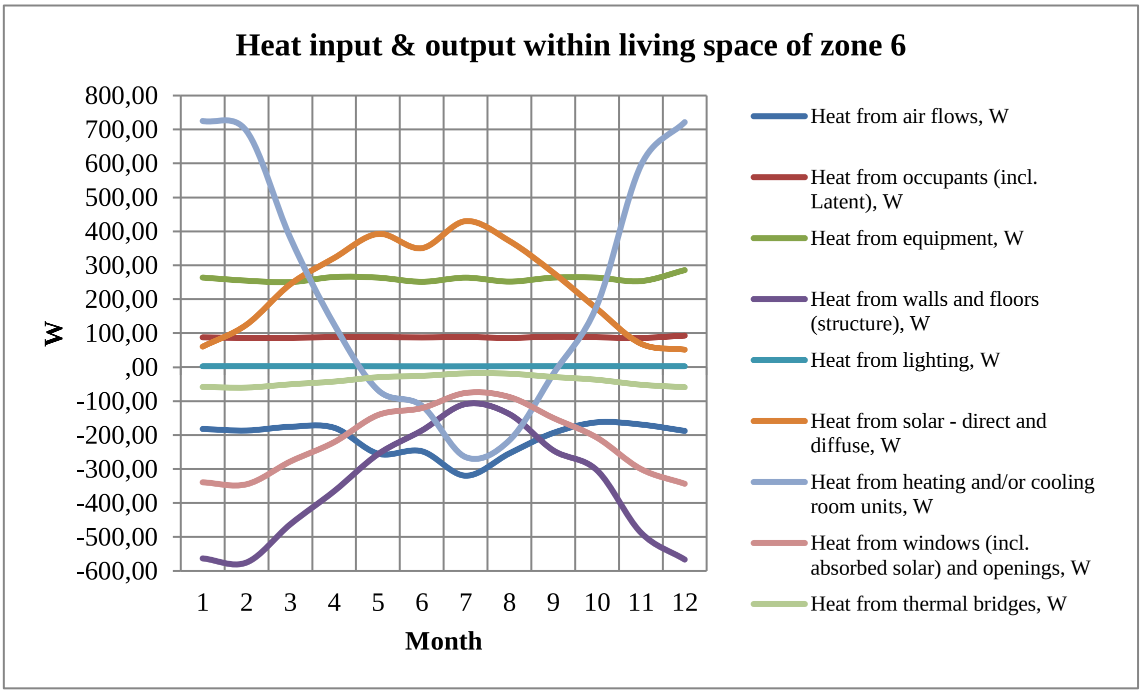
Zone 5

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-289.8	214.8	477.9	-866.1	10.3	56.33	902.3	-429.8	-75.44	0.0
February	-295.8	213.1	474.9	-868.6	10.4	121.4	856.4	-434.0	-77.43	0.0
March	-290.0	213.1	469.6	-662.5	10.05	246.4	422.5	-345.8	-63.47	0.0
April	-316.1	216.0	477.0	-494.4	9.217	334.5	97.96	-273.8	-52.33	0.0
May	-394.3	216.3	477.8	-362.6	8.614	409.7	-142.4	-177.4	-36.49	0.0
June	-404.8	215.1	467.9	-280.3	8.605	406.3	-229.6	-151.4	-32.15	0.0
July	-386.4	216.8	477.8	-155.5	7.913	477.2	-516.2	-99.49	-22.62	0.0
August	-352.2	213.9	476.6	-203.5	8.875	396.9	-401.1	-115.7	-23.93	0.0
September	-332.0	217.5	469.2	-341.3	9.712	254.3	-54.33	-190.0	-35.37	0.0
October	-279.9	215.4	477.3	-443.9	10.16	162.0	163.6	-260.1	-46.69	0.0
November	-273.8	212.6	475.9	-731.1	10.45	65.09	681.4	-374.5	-66.25	0.0
December	-297.5	221.2	472.6	-913.3	9.75	44.97	979.7	-439.0	-77.59	0.0
mean	-326.1	215.5	474.6	-525.7	9.498	248.4	227.7	-273.7	-50.71	0.0
mean*8784.0 h	-2864881.6	1892981.8	4168572.6	-4618130.1	83432.2	2182284.9	2000373.3	-2403812.6	-445473.7	0.0
min	-404.8	212.6	467.9	-913.3	7.913	44.97	-516.2	-439.0	-77.59	0.0
max	-273.8	221.2	477.9	-155.5	10.45	477.2	979.7	-99.49	-22.62	0.0



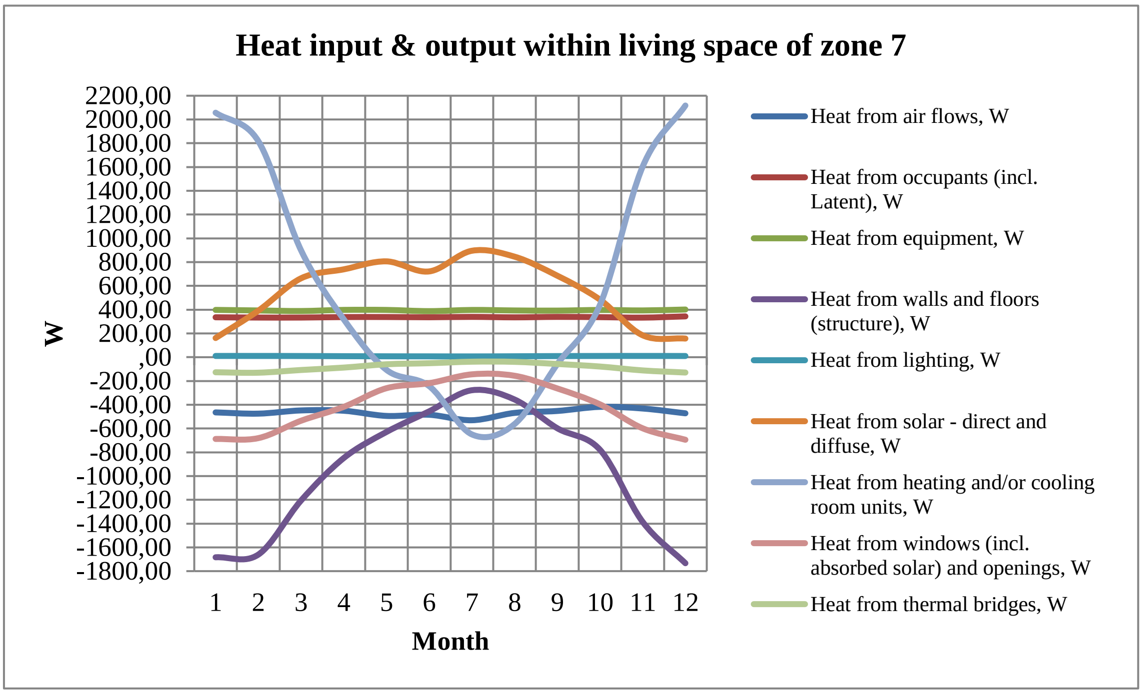
Zone 6

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-181.6	88.0	264.1	-562.8	2.888	60.79	725.3	-338.8	-57.95	0.0
February	-186.3	86.66	255.0	-574.9	2.876	125.4	695.8	-344.6	-59.8	0.0
March	-175.3	86.72	250.7	-462.3	2.844	244.4	380.9	-277.5	-50.2	0.0
April	-178.1	88.78	265.8	-364.9	2.812	321.7	126.2	-220.6	-42.09	0.0
May	-254.4	88.63	264.0	-256.0	2.712	392.7	-67.29	-140.7	-29.28	0.0
June	-247.3	87.8	251.7	-186.3	2.595	350.6	-113.1	-120.3	-25.34	0.0
July	-319.3	88.86	263.9	-108.3	2.612	430.3	-264.5	-75.64	-17.97	0.0
August	-253.6	86.59	252.2	-137.9	2.771	371.7	-215.0	-87.53	-18.93	0.0
September	-193.4	89.91	264.0	-244.7	2.839	278.6	-19.93	-149.2	-28.51	0.0
October	-162.1	88.32	263.8	-303.6	2.873	171.9	182.7	-207.5	-36.86	0.0
November	-168.6	86.26	253.6	-486.9	2.88	69.4	594.4	-299.6	-51.42	0.0
December	-187.4	93.2	286.0	-566.2	2.857	51.72	721.7	-343.0	-58.74	0.0
mean	-209.2	88.32	261.3	-353.7	2.796	239.5	227.2	-216.6	-39.68	0.0
mean*8784.0 h	-1837797.0	775805.2	2295226.0	-3106938.1	24563.4	2104020.5	1996156.3	-1902678.5	-348524.8	0.0
min	-319.3	86.26	250.7	-574.9	2.595	51.72	-264.5	-344.6	-59.8	0.0
max	-162.1	93.2	286.0	-108.3	2.888	430.3	725.3	-75.64	-17.97	0.0



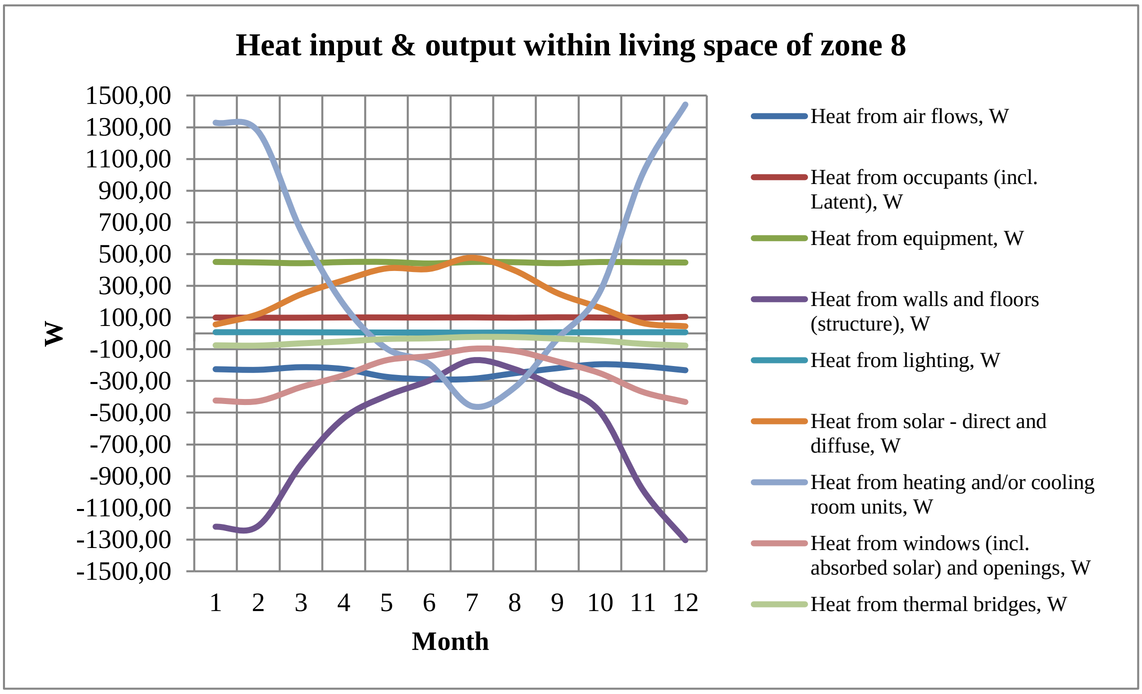
Zone 7

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-465.4	335.9	397.9	-1683.4	10.56	161.4	2057.0	-687.7	-126.6	0.0
February	-474.8	333.7	393.3	-1660.6	10.57	391.3	1818.0	-680.8	-130.4	0.0
March	-447.8	333.6	388.6	-1206.0	9.887	663.7	899.9	-534.5	-107.6	0.0
April	-450.5	337.7	397.9	-848.4	8.459	739.2	318.8	-417.6	-87.22	0.0
May	-493.9	338.2	397.7	-629.1	7.543	806.3	-106.2	-260.8	-59.52	0.0
June	-484.4	336.2	387.6	-455.7	7.1	721.9	-243.0	-218.6	-50.49	0.0
July	-530.3	339.3	397.6	-277.9	6.609	895.5	-649.5	-144.3	-37.73	0.0
August	-468.7	335.4	393.3	-355.9	7.821	845.9	-562.3	-156.1	-38.97	0.0
September	-452.3	339.3	392.1	-597.6	9.495	685.6	-58.17	-262.9	-56.99	0.0
October	-417.8	337.0	397.4	-778.6	10.29	484.4	440.5	-396.7	-78.5	0.0
November	-431.6	333.1	393.6	-1385.3	10.63	184.3	1604.1	-598.2	-111.2	0.0
December	-472.1	343.6	401.2	-1733.4	10.14	156.9	2117.5	-694.4	-128.9	0.0
mean	-465.9	336.9	394.9	-965.4	9.086	562.0	632.4	-420.1	-84.34	0.0
mean*8784.0 h	-4092116.4	2959639.8	3468710.1	-8480241.0	79810.2	4936990.0	5554975.0	-3690369.8	-740833.3	0.0
min	-530.3	333.1	387.6	-1733.4	6.609	156.9	-649.5	-694.4	-130.4	0.0
max	-417.8	343.6	401.2	-277.9	10.63	895.5	2117.5	-144.3	-37.73	0.0



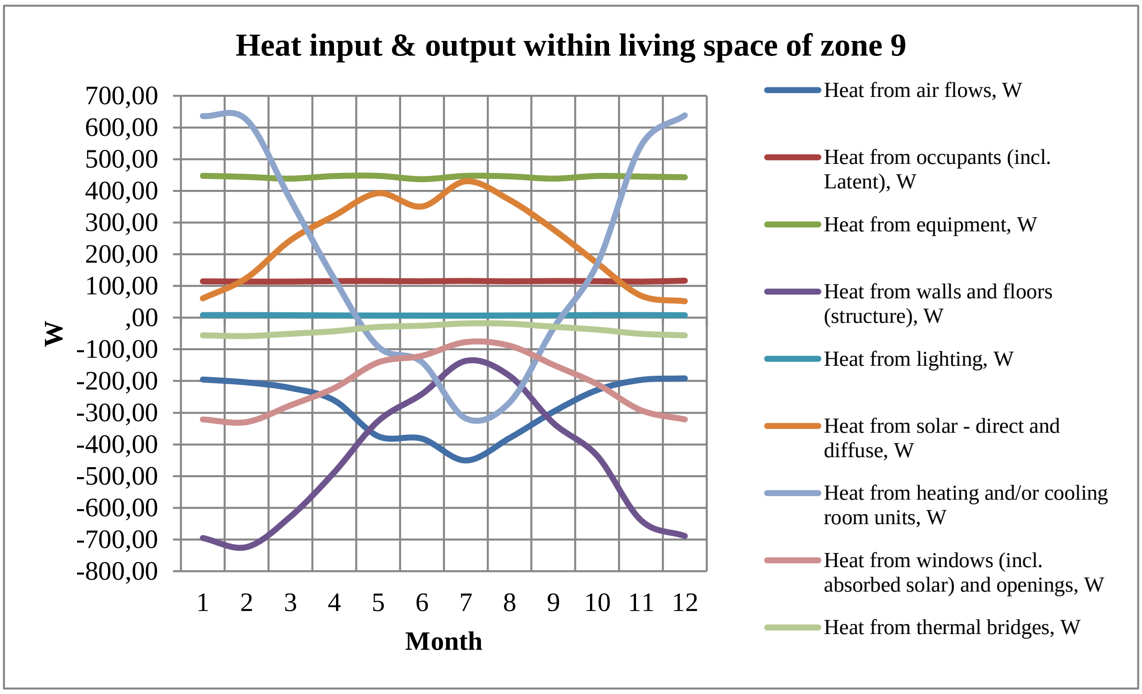
Zone 8

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-225.7	100.1	450.7	-1219.0	7.508	56.34	1328.7	-423.3	-74.96	0.0
February	-229.6	99.05	447.6	-1213.5	7.553	121.4	1272.1	-427.1	-76.9	0.0
March	-213.0	99.16	442.6	-828.0	7.14	246.4	646.9	-338.6	-62.72	0.0
April	-224.9	100.7	450.0	-534.8	6.346	334.5	181.4	-264.0	-50.82	0.0
May	-274.0	100.7	450.6	-393.9	5.722	409.8	-94.86	-169.2	-35.23	0.0
June	-289.2	100.2	441.0	-297.8	5.569	406.4	-192.3	-143.1	-30.87	0.0
July	-286.4	101.0	450.6	-170.2	5.124	477.2	-458.7	-97.04	-22.32	0.0
August	-251.3	99.19	448.9	-225.0	5.932	397.0	-341.2	-110.3	-23.19	0.0
September	-219.4	101.7	442.8	-342.7	6.827	254.4	-35.49	-176.8	-33.15	0.0
October	-194.5	100.3	450.2	-494.6	7.382	162.1	263.9	-251.1	-45.31	0.0
November	-206.4	98.71	448.4	-984.7	7.61	65.11	1005.8	-368.8	-65.8	0.0
December	-232.2	104.2	447.0	-1303.8	6.996	44.99	1443.1	-432.4	-77.1	0.0
mean	-237.3	100.4	447.6	-665.7	6.638	248.5	415.5	-266.2	-49.76	0.0
mean*8784.0 h	-2084430.6	882235.4	3931378.8	-5847596.6	58308.8	2182419.4	3649941.1	-2338695.4	-437135.7	0.0
min	-289.2	98.71	441.0	-1303.8	5.124	44.99	-458.7	-432.4	-77.1	0.0
max	-194.5	104.2	450.7	-170.2	7.61	477.2	1443.1	-97.04	-22.32	0.0



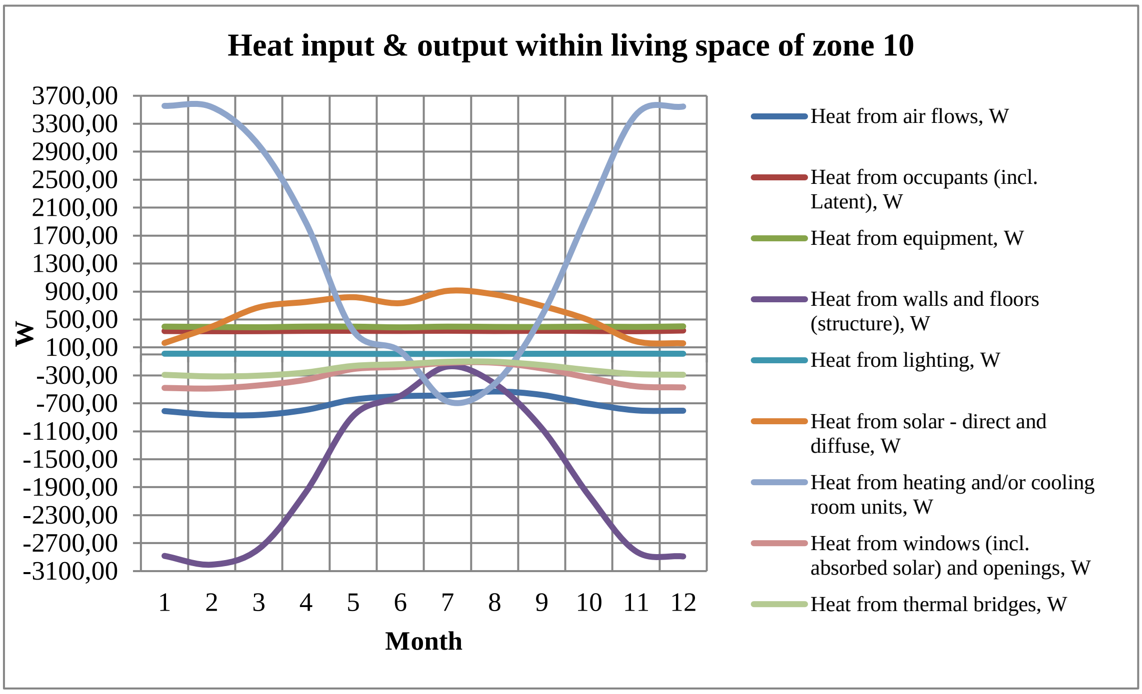
Zone 9

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-195.2	114.5	447.5	-695.3	8.109	60.73	636.1	-321.1	-55.76	0.0
February	-204.3	113.8	444.1	-723.8	8.119	125.3	623.9	-329.3	-58.1	0.0
March	-221.8	113.8	438.6	-627.7	7.678	244.3	372.1	-276.6	-50.83	0.0
April	-261.2	115.2	446.7	-488.0	7.047	321.6	122.4	-222.2	-42.82	0.0
May	-374.0	115.5	447.4	-326.5	6.789	392.6	-91.28	-141.3	-29.52	0.0
June	-381.7	114.8	436.9	-241.0	6.663	350.6	-140.4	-120.5	-25.45	0.0
July	-450.6	115.8	447.3	-136.5	6.627	430.2	-317.8	-77.13	-18.29	0.0
August	-379.9	114.6	445.7	-183.6	6.992	371.6	-267.7	-88.53	-19.18	0.0
September	-297.0	115.6	438.6	-332.6	7.372	278.5	-34.08	-149.0	-28.65	0.0
October	-228.4	115.0	447.0	-435.9	7.986	171.8	168.9	-209.9	-37.79	0.0
November	-196.5	113.7	445.1	-639.3	8.19	69.34	542.3	-292.2	-50.97	0.0
December	-191.6	116.6	443.0	-688.9	7.657	51.67	638.4	-321.1	-55.78	0.0
mean	-282.2	114.9	444.0	-458.8	7.433	239.5	186.0	-211.9	-39.35	0.0
mean*8784.0 h	-2479235.5	1009441.3	3900180.2	-4030478.5	65295.5	2103562.3	1634036.0	-1861709.5	-345668.2	0.0
min	-450.6	113.7	436.9	-723.8	6.627	51.67	-317.8	-329.3	-58.1	0.0
max	-191.6	116.6	447.5	-136.5	8.19	430.2	638.4	-77.13	-18.29	0.0



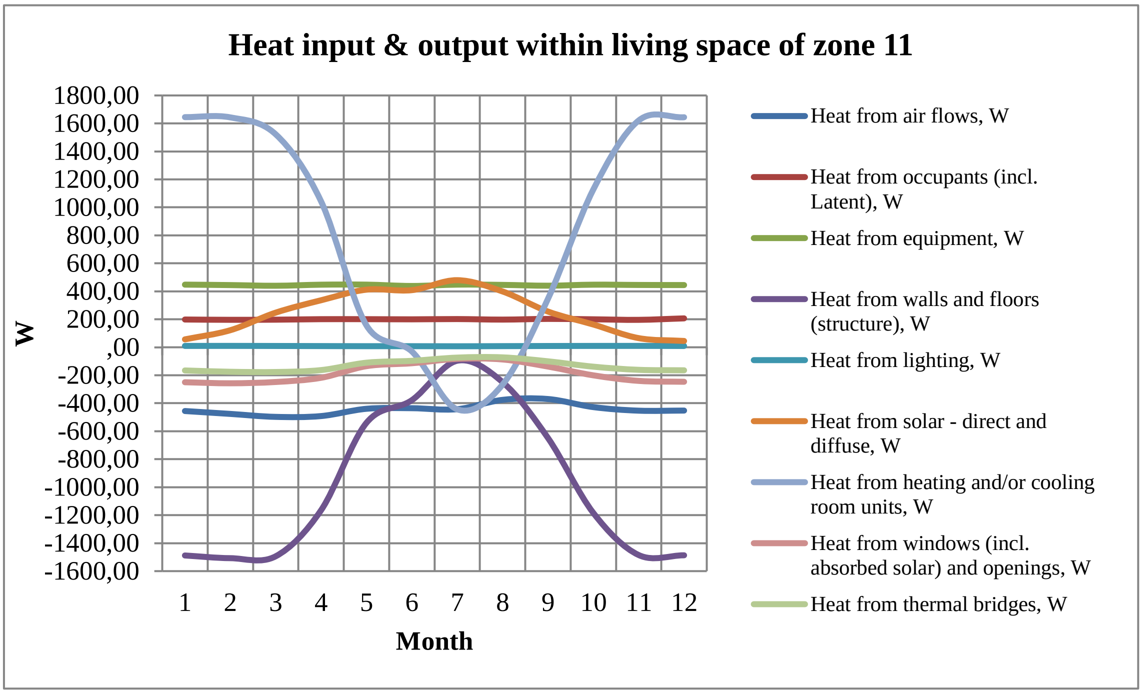
Zone 10

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-810.5	334.2	397.9	-2882.2	10.56	163.8	3555.9	-479.1	-292.1	0.0
February	-863.2	332.0	393.3	-3007.2	10.57	396.9	3539.3	-487.1	-314.2	0.0
March	-866.2	332.7	388.6	-2782.4	9.894	673.3	2992.1	-443.3	-303.8	0.0
April	-793.2	337.1	397.9	-1968.0	8.608	750.5	1885.6	-362.2	-257.8	0.0
May	-647.5	337.5	397.7	-880.4	7.677	818.8	341.0	-208.8	-164.3	0.0
June	-597.9	335.6	387.6	-594.7	7.307	733.4	46.56	-176.6	-139.7	0.0
July	-583.3	338.9	397.6	-173.2	6.746	909.3	-672.5	-119.6	-106.2	0.0
August	-530.2	334.9	393.3	-416.2	8.027	858.6	-423.8	-118.2	-104.6	0.0
September	-579.1	338.4	392.1	-1056.2	9.564	695.7	548.3	-199.3	-151.9	0.0
October	-704.8	336.3	397.4	-2018.4	10.3	491.4	2042.7	-333.3	-224.4	0.0
November	-799.9	331.9	393.6	-2817.5	10.63	187.2	3430.1	-456.0	-281.7	0.0
December	-805.3	341.7	401.2	-2889.7	10.14	159.2	3546.5	-471.9	-290.8	0.0
mean	-714.5	336.0	394.9	-1785.7	9.162	570.5	1728.8	-320.6	-218.9	0.0
mean*8784.0 h	-6276314.2	2951093.1	3468710.1	-1.56859728E7	80480.4	5011423.7	1.51860589E7	-2816298.3	-1922793.2	0.0
min	-866.2	331.9	387.6	-3007.2	6.746	159.2	-672.5	-487.1	-314.2	0.0
max	-530.2	341.7	401.2	-173.2	10.63	909.3	3555.9	-118.2	-104.6	0.0



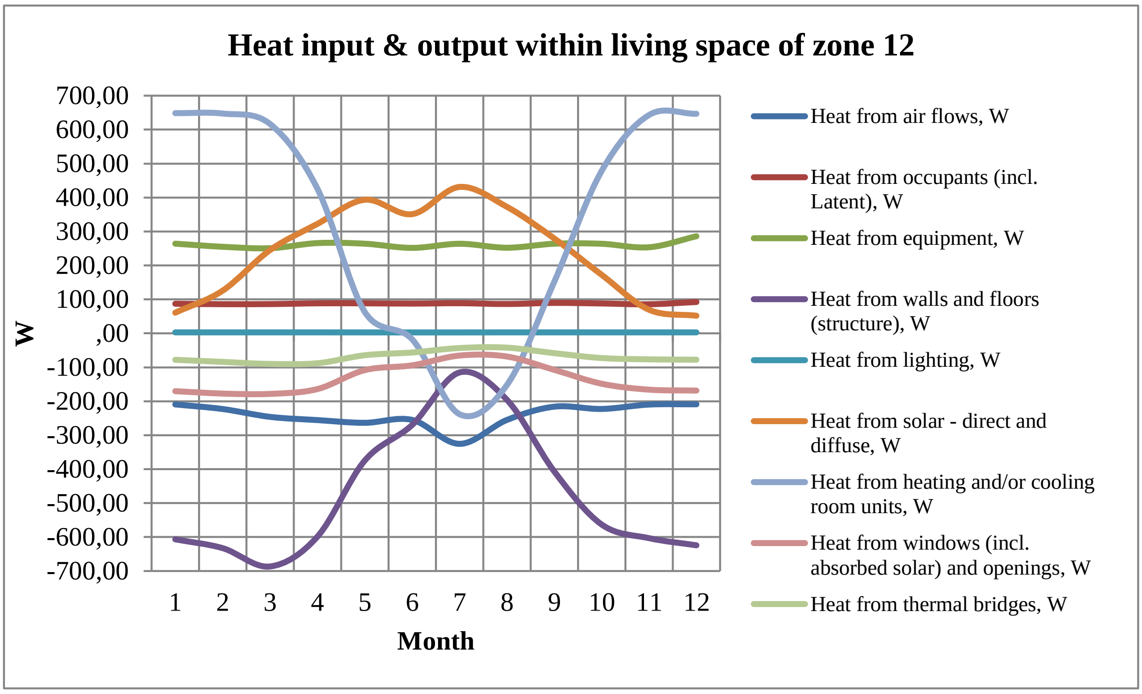
Zone 11

	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-455.5	198.5	447.9	-1488.0	9.857	56.61	1645.0	-249.8	-165.6	0.0
February	-476.2	196.5	444.7	-1507.4	9.906	122.0	1643.3	-257.3	-175.0	0.0
March	-497.4	197.4	439.8	-1493.7	9.475	247.7	1522.4	-248.0	-176.7	0.0
April	-491.6	200.9	447.4	-1164.8	8.555	336.2	1043.2	-218.1	-163.0	0.0
May	-439.5	200.9	447.9	-540.0	7.946	411.9	156.8	-135.0	-110.1	0.0
June	-435.4	199.9	438.4	-378.2	7.936	408.4	-29.52	-114.0	-96.79	0.0
July	-442.4	201.7	447.9	-96.26	7.321	479.7	-443.4	-82.71	-73.63	0.0
August	-375.7	198.0	446.0	-248.9	8.202	399.0	-266.6	-87.11	-71.93	0.0
September	-369.8	202.9	440.3	-648.0	9.141	255.6	346.2	-137.8	-100.2	0.0
October	-427.6	200.1	447.5	-1183.8	9.7	162.9	1127.9	-200.4	-138.6	0.0
November	-453.0	196.2	445.5	-1485.0	9.983	65.41	1621.2	-240.2	-161.1	0.0
December	-452.3	206.7	444.8	-1486.7	9.315	45.2	1644.3	-246.4	-164.4	0.0
mean	-442.9	200.0	444.9	-974.4	8.94	249.7	830.7	-184.4	-132.9	0.0
mean*8784.0 h	-3890550.3	1756779.1	3907569.4	-8559412.3	78527.3	2193486.3	7297158.3	-1619685.3	-1167296.3	0.0
min	-497.4	196.2	438.4	-1507.4	7.321	45.2	-443.4	-257.3	-176.7	0.0
max	-369.8	206.7	447.9	-96.26	9.983	479.7	1645.0	-82.71	-71.93	0.0



Zone 12

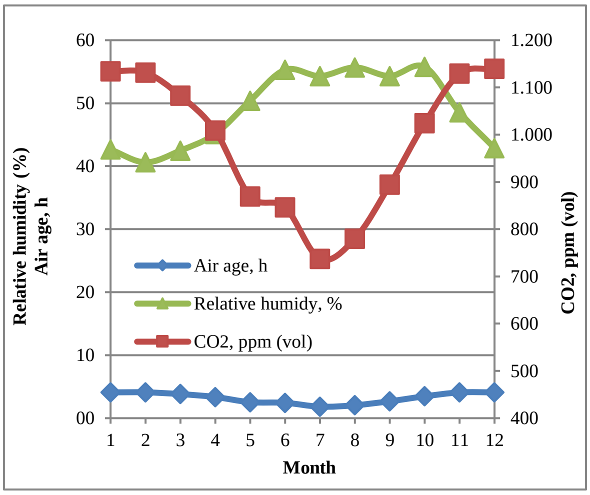
	Variables									
	Heat from air flows, W	Heat from occupants (incl. latent), W	Heat from equipment, W	Heat from walls and floors (structure), W	Heat from lighting, W	Heat from solar - direct and diffuse, W	Heat from heating and/or cooling room units, W	Heat from windows (including absorbed solar) and openings, W	Heat from thermal bridges, W	Net losses, W
January	-209.3	87.23	264.1	-606.7	2.888	60.9	648.5	-170.3	-77.9	0.0
February	-222.9	85.91	255.0	-632.6	2.876	125.7	647.4	-177.4	-84.07	0.0
March	-246.0	86.22	250.7	-686.6	2.847	245.2	616.7	-178.3	-90.09	0.0
April	-255.5	88.46	265.8	-598.9	2.844	322.4	426.2	-164.1	-88.07	0.0
May	-263.5	88.4	264.0	-374.7	2.79	393.5	63.07	-108.3	-64.46	0.0
June	-254.9	87.61	251.7	-269.8	2.684	351.1	-17.48	-94.2	-56.4	0.0
July	-325.4	88.77	263.9	-115.1	2.722	431.2	-238.2	-65.35	-43.19	0.0
August	-255.0	86.43	252.2	-195.7	2.831	372.6	-152.2	-68.28	-42.15	0.0
September	-215.9	89.64	264.0	-406.8	2.842	279.3	152.1	-107.6	-58.37	0.0
October	-222.7	88.01	263.8	-563.0	2.873	172.4	478.4	-148.4	-72.73	0.0
November	-209.7	85.65	253.6	-603.2	2.88	69.48	643.1	-165.8	-76.57	0.0
December	-208.9	92.37	286.0	-624.3	2.857	51.85	646.6	-168.6	-77.6	0.0
mean	-241.0	87.9	261.3	-472.3	2.828	240.1	324.7	-134.5	-69.21	0.0
mean*8784.0 h	-2116792.2	772140.0	2295226.0	-4148427.8	24839.9	2108946.5	2852008.6	-1181372.3	-607948.5	0.0
min	-325.4	85.65	250.7	-686.6	2.684	51.85	-238.2	-178.3	-90.09	0.0
max	-208.9	92.37	286.0	-115.1	2.888	431.2	648.5	-65.35	-42.15	0.0



Appendix 17 Average monthly indoor air quality

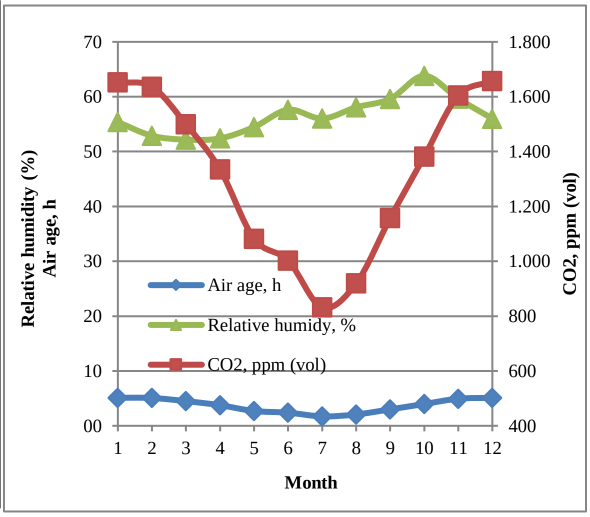
Zone 1

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	4.101	1134.2	42.64
February	4.101	1131.4	40.61
March	3.823	1082.3	42.48
April	3.361	1008.5	45.12
May	2.539	869.5	50.4
June	2.442	846.3	55.3
July	1.822	737.2	54.3
August	2.053	779.8	55.68
September	2.686	894.0	54.31
October	3.47	1024.5	55.76
November	4.089	1129.1	48.55
December	4.103	1139.3	42.88
mean	3.212	980.6	49.03
mean*8784.0 h	28211.6	8613927.8	430689.8
min	1.822	737.2	40.61
max	4.103	1139.3	55.76



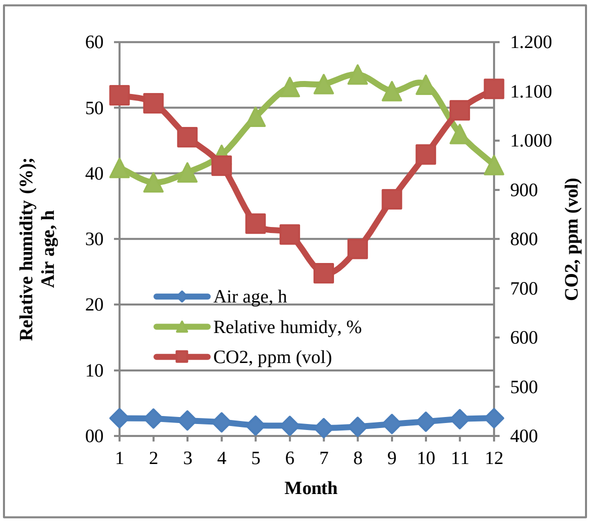
Zone 2

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	5.114	1652.4	55.37
February	5.067	1636.6	52.88
March	4.498	1499.4	52.17
April	3.761	1334.8	52.4
May	2.693	1082.2	54.47
June	2.395	1002.9	57.62
July	1.717	831.8	56.01
August	2.066	919.5	58.07
September	3.002	1157.5	59.6
October	3.976	1382.1	63.81
November	4.938	1604.2	59.65
December	5.097	1657.1	56.0
mean	3.688	1312.0	56.52
mean*8784.0 h	32395.4	1.15246932E7	496444.2
min	1.717	831.8	52.17
max	5.114	1657.1	63.81



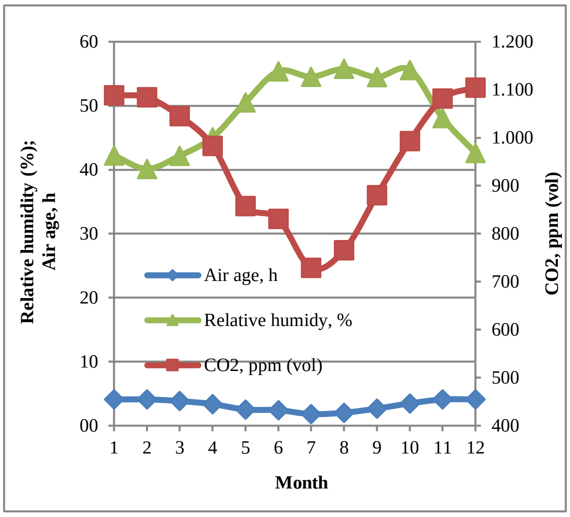
Zone 3

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	2.696	1092.1	40.85
February	2.642	1075.9	38.63
March	2.352	1007.3	40.17
April	2.095	949.1	42.84
May	1.617	831.6	48.63
June	1.545	809.5	53.2
July	1.225	730.6	53.63
August	1.42	780.2	55.07
September	1.821	881.0	52.57
October	2.194	971.6	53.54
November	2.579	1061.7	46.02
December	2.733	1104.9	41.28
mean	2.074	940.7	47.24
mean*8784.0 h	18219.7	8263358.0	414913.3
min	1.225	730.6	38.63
max	2.733	1104.9	55.07



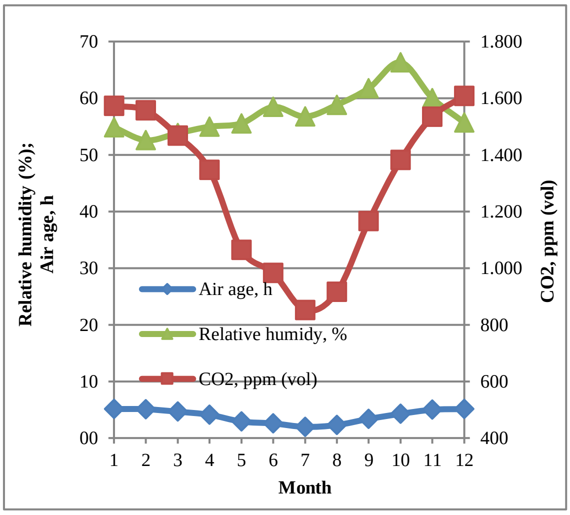
Zone 4

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	4.107	1088.5	42.22
February	4.107	1084.2	40.15
March	3.853	1045.1	42.18
April	3.376	983.2	45.06
May	2.529	857.9	50.53
June	2.43	831.2	55.38
July	1.813	728.9	54.52
August	2.026	765.3	55.77
September	2.673	880.2	54.47
October	3.484	992.8	55.6
November	4.098	1081.5	48.1
December	4.108	1104.6	42.64
mean	3.213	953.0	48.91
mean*8784.0 h	28222.2	8371111.9	429657.0
min	1.813	728.9	40.15
max	4.108	1104.6	55.77



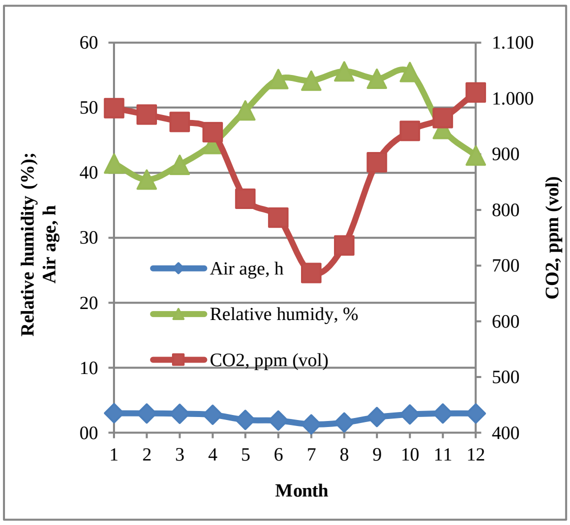
Zone 5

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	5.128	1572.7	54.85
February	5.089	1556.8	52.57
March	4.654	1467.7	53.81
April	4.108	1346.1	54.97
May	2.908	1064.5	55.54
June	2.585	982.5	58.45
July	1.972	852.0	56.75
August	2.298	915.7	58.82
September	3.377	1165.5	61.74
October	4.272	1381.1	66.31
November	5.002	1534.7	59.99
December	5.12	1607.2	55.69
mean	3.871	1286.1	57.47
mean*8784.0 h	33999.8	1.12967305E7	504827.3
min	1.972	852.0	52.57
max	5.128	1607.2	66.31



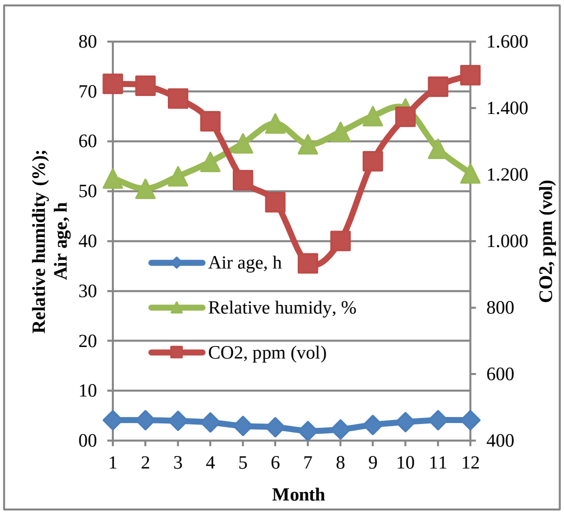
Zone 6

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	2.984	982.7	41.43
February	2.973	970.8	38.94
March	2.923	957.8	41.22
April	2.757	939.6	44.42
May	1.966	819.7	49.6
June	1.858	786.2	54.38
July	1.285	686.7	54.16
August	1.551	736.3	55.6
September	2.386	885.5	54.45
October	2.813	941.4	55.48
November	2.963	964.4	46.71
December	2.96	1010.8	42.64
mean	2.448	889.7	48.29
mean*8784.0 h	21506.4	7814827.5	424155.8
min	1.285	686.7	38.94
max	2.984	1010.8	55.6



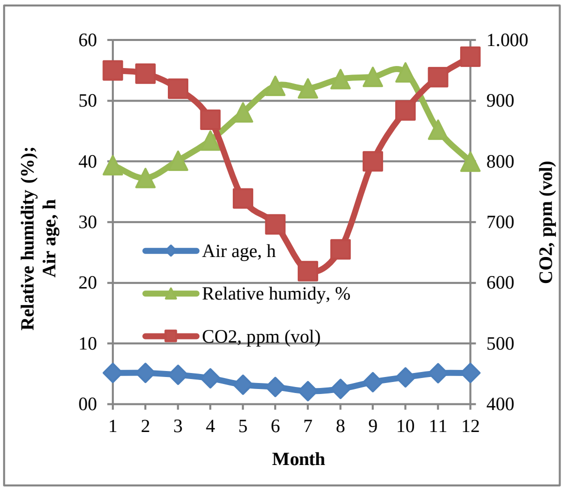
Zone 7

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	4.108	1473.6	52.58
February	4.107	1467.5	50.52
March	3.957	1429.2	52.99
April	3.654	1360.3	55.9
May	2.933	1184.0	59.61
June	2.703	1117.7	63.59
July	1.962	933.0	59.44
August	2.243	1000.9	61.91
September	3.168	1240.7	65.09
October	3.723	1374.4	66.61
November	4.102	1464.8	58.53
December	4.109	1499.8	53.6
mean	3.393	1294.5	58.38
mean*8784.0 h	29807.0	1.1371311E7	512817.7
min	1.962	933.0	50.52
max	4.109	1499.8	66.61



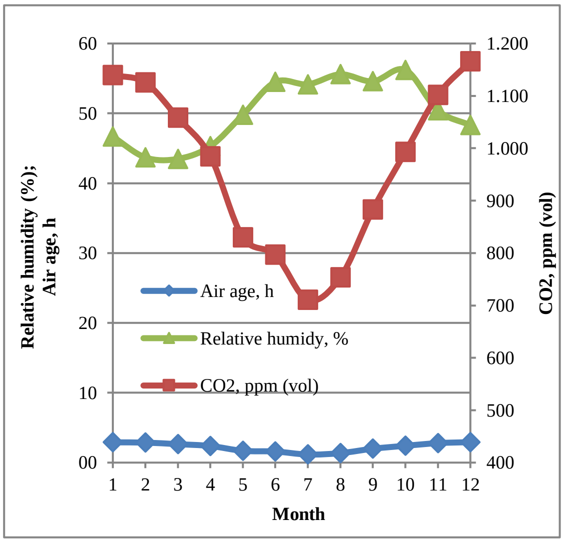
Zone 8

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	5.145	949.8	39.37
February	5.141	944.6	37.25
March	4.83	919.8	40.12
April	4.261	868.8	43.46
May	3.198	738.8	48.07
June	2.824	696.5	52.44
July	2.14	619.5	52.01
August	2.514	655.1	53.57
September	3.655	800.0	53.93
October	4.433	883.9	54.69
November	5.096	939.0	45.23
December	5.139	972.3	39.95
mean	4.026	831.8	46.7
mean*8784.0 h	35365.4	7306467.6	410255.3
min	2.14	619.5	37.25
max	5.145	972.3	54.69



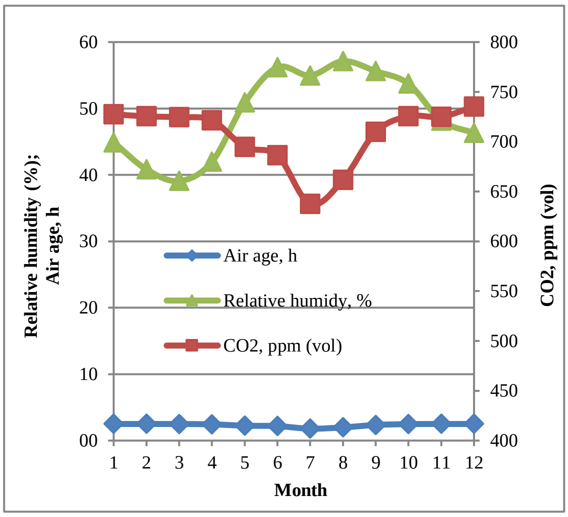
Zone 9

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	2.899	1139.5	46.66
February	2.864	1125.5	43.69
March	2.638	1058.1	43.48
April	2.38	984.7	45.28
May	1.686	829.9	49.8
June	1.589	796.7	54.49
July	1.157	710.5	54.16
August	1.359	753.5	55.59
September	1.986	883.0	54.58
October	2.409	992.9	56.21
November	2.789	1101.5	50.41
December	2.933	1165.7	48.3
mean	2.221	961.1	50.25
mean*8784.0 h	19509.5	8442381.2	441383.6
min	1.157	710.5	43.48
max	2.933	1165.7	56.21



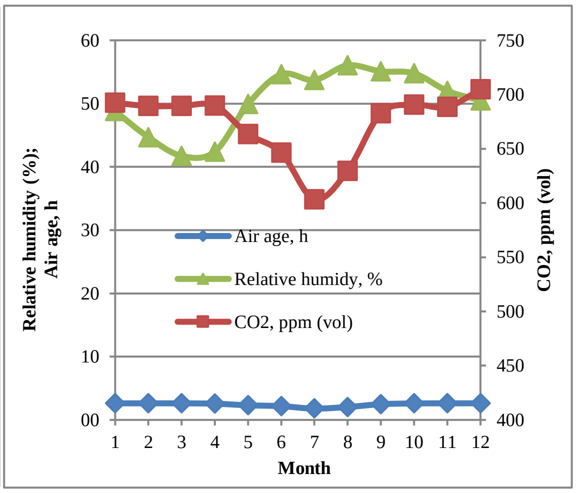
Zone 10

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	2.498	727.5	44.9
February	2.499	725.4	40.83
March	2.492	724.5	39.08
April	2.444	721.5	41.97
May	2.243	694.7	50.88
June	2.175	686.2	56.19
July	1.795	637.4	54.96
August	1.985	661.6	57.12
September	2.351	709.8	55.6
October	2.477	725.5	53.72
November	2.498	725.0	48.17
December	2.498	735.2	46.32
mean	2.328	706.0	49.18
mean*8784.0 h	20451.0	6201940.7	431975.7
min	1.795	637.4	39.08
max	2.499	735.2	57.12



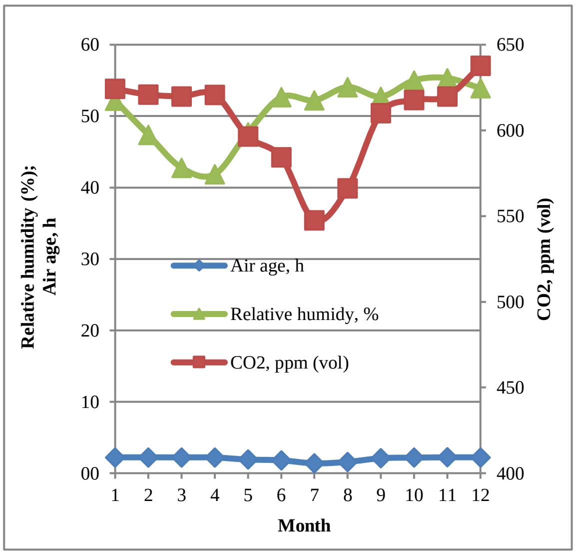
Zone 11

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	2.624	692.3	48.79
February	2.623	689.4	44.68
March	2.619	689.4	41.73
April	2.568	689.7	42.4
May	2.313	663.6	49.91
June	2.171	646.4	54.62
July	1.793	603.4	53.73
August	2.043	629.7	56.04
September	2.483	682.7	55.09
October	2.606	690.6	54.78
November	2.624	688.5	52.01
December	2.624	704.7	50.47
mean	2.423	672.4	50.38
mean*8784.0 h	21282.3	5906399.8	442538.3
min	1.793	603.4	41.73
max	2.624	704.7	56.04



Zone 12

	Variables		
	Air age, h	CO2, ppm (vol)	Relative humidity, %
January	2.22	624.2	52.17
February	2.219	620.9	47.38
March	2.214	619.9	42.76
April	2.194	620.8	41.87
May	1.91	596.4	47.72
June	1.804	584.3	52.66
July	1.378	547.6	52.22
August	1.581	566.2	54.07
September	2.097	610.1	52.73
October	2.178	617.7	55.01
November	2.221	619.9	55.33
December	2.22	637.7	53.9
mean	2.018	605.3	50.67
mean*8784.0 h	17724.8	5317299.6	445100.5
min	1.378	547.6	41.87
max	2.221	637.7	55.33



Appendix 18 Fanger's comfort indices

Zone 1

	Variables			
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PPD, Predicted Percentage of Dissatisfied, at occupant 2, %	PMV, Predicted Mean Vote, at occupant 1	PMV, Predicted Mean Vote, at occupant 2
January	7.209	7.06	0.3216	0.3101
February	7.625	7.471	0.3482	0.337
March	10.11	9.949	0.4672	0.4576
April	14.05	13.86	0.6175	0.6087
May	24.22	23.98	0.924	0.9167
June	26.65	26.39	0.9874	0.9804
July	34.11	33.9	1.171	1.166
August	32.07	31.89	1.121	1.117
September	21.41	21.22	0.8587	0.8525
October	14.18	14.01	0.6171	0.6093
November	7.887	7.735	0.3647	0.3543
December	7.161	7.018	0.3155	0.304
mean	17.27	17.09	0.6776	0.6692
mean*8784.0 h	151726.7	150119.7	5952.2	5878.6
min	7.161	7.018	0.3155	0.304
max	34.11	33.9	1.171	1.166

Zone 2

	Variables			
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PPD, Predicted Percentage of Dissatisfied, at occupant 2, %	PMV, Predicted Mean Vote, at occupant 1	PMV, Predicted Mean Vote, at occupant 2
January	7.52	7.372	0.3298	0.3189
February	7.707	7.553	0.3383	0.3271
March	10.09	9.883	0.4745	0.4638
April	14.62	14.37	0.6485	0.6387
May	25.93	25.61	0.9727	0.9645
June	29.52	29.21	1.066	1.059
July	35.41	35.15	1.199	1.193
August	33.49	33.21	1.157	1.15
September	22.59	22.29	0.9011	0.8928
October	14.25	14.02	0.6348	0.6258
November	8.673	8.505	0.4014	0.3911
December	7.173	7.044	0.296	0.2853
mean	18.13	17.9	0.703	0.694
mean*8784.0 h	159252.9	157229.6	6175.3	6095.8
min	7.173	7.044	0.296	0.2853
max	35.41	35.15	1.199	1.193

Zone 3

	Variables	
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PMV, Predicted Mean Vote, at occupant 1
January	7.845	0.3536
February	7.999	0.3609
March	10.26	0.4745
April	14.9	0.6495
May	25.39	0.9579
June	28.26	1.032
July	34.26	1.173
August	32.37	1.129
September	22.67	0.8985
October	14.33	0.6286
November	8.702	0.4021
December	7.737	0.3443
mean	17.94	0.7018
mean*8784.0 h	157584.8	6164.2
min	7.737	0.3443
max	34.26	1.173

Zone 4

	Variables			
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PPD, Predicted Percentage of Dissatisfied, at occupant 2, %	PMV, Predicted Mean Vote, at occupant 1	PMV, Predicted Mean Vote, at occupant 2
January	7.166	7.761	0.3195	0.378
February	7.552	8.14	0.344	0.3944
March	9.962	10.54	0.4605	0.481
April	13.87	14.66	0.6118	0.6091
May	24.04	24.55	0.9195	0.8595
June	26.5	26.77	0.9837	0.9108
July	34.05	33.8	1.17	1.063
August	31.97	31.42	1.119	1.009
September	21.25	22.32	0.854	0.8176
October	14.01	14.97	0.6113	0.6152
November	7.808	8.42	0.3603	0.4069
December	7.172	8.011	0.3183	0.3894
mean	17.16	17.66	0.6741	0.6624
mean*8784.0 h	150751.6	155130.7	5921.6	5818.4
min	7.166	7.761	0.3183	0.378
max	34.05	33.8	1.17	1.063

Zone 5

	Variables			
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PPD, Predicted Percentage of Dissatisfied, at occupant 2, %	PMV, Predicted Mean Vote, at occupant 1	PMV, Predicted Mean Vote, at occupant 2
January	9.325	10.3	0.4453	0.4932
February	9.361	10.36	0.4457	0.4946
March	11.09	12.28	0.508	0.5654
April	15.72	17.45	0.647	0.7218
May	26.68	30.01	0.9101	1.025
June	29.71	33.42	0.979	1.101
July	35.09	39.43	1.089	1.225
August	32.83	37.19	1.04	1.178
September	23.96	26.59	0.8617	0.9591
October	15.46	17.12	0.6394	0.7116
November	10.07	11.16	0.4727	0.5259
December	9.501	10.32	0.4542	0.4942
mean	19.11	21.35	0.7088	0.7925
mean*8784.0 h	167860.0	187566.6	6225.7	6961.6
min	9.325	10.3	0.4453	0.4932
max	35.09	39.43	1.089	1.225

Zone 6

	Variables	
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PMV, Predicted Mean Vote, at occupant 1
January	6.116	0.2874
February	6.149	0.288
March	8.108	0.3805
April	12.03	0.5133
May	21.66	0.7617
June	23.9	0.8132
July	29.24	0.9296
August	26.8	0.8729
September	19.44	0.7193
October	11.79	0.5041
November	6.945	0.3304
December	6.265	0.2855
mean	14.91	0.5582
mean*8784.0 h	130972.2	4903.6
min	6.116	0.2855
max	29.24	0.9296

Zone 7

	Variables					
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PPD, Predicted Percentage of Dissatisfied, at occupant 2, %	PPD, Predicted Percentage of Dissatisfied, at occupant 3, %	PMV, Predicted Mean Vote, at occupant 1	PMV, Predicted Mean Vote, at occupant 2	PMV, Predicted Mean Vote, at occupant 3
January	7.735	9.134	8.504	0.3758	0.4433	0.4133
February	8.02	9.522	8.845	0.3892	0.4624	0.4295
March	10.46	12.41	11.57	0.4813	0.5739	0.5315
April	14.47	17.18	16.08	0.6059	0.7236	0.67
May	24.88	30.02	27.58	0.8668	1.049	0.9561
June	26.87	32.44	29.66	0.911	1.101	1.001
July	34.65	42.07	38.15	1.08	1.312	1.186
August	31.85	39.17	35.35	1.017	1.249	1.124
September	22.03	26.13	24.37	0.81	0.964	0.8904
October	14.83	17.54	16.36	0.6134	0.7299	0.6744
November	8.559	10.16	9.411	0.413	0.4911	0.4542
December	7.707	8.822	8.35	0.3711	0.4232	0.4022
mean	17.72	21.28	19.57	0.6624	0.7951	0.7291
mean*8784.0 h	155663.1	186899.1	171938.1	5818.5	6983.8	6404.0
min	7.707	8.822	8.35	0.3711	0.4232	0.4022
max	34.65	42.07	38.15	1.08	1.312	1.186

Zone 8

	Variables	
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PMV, Predicted Mean Vote, at occupant 1
January	7.66	0.3712
February	7.671	0.3706
March	9.22	0.4366
April	13.01	0.5653
May	23.55	0.8382
June	26.57	0.909
July	33.23	1.053
August	30.3	0.9879
September	19.86	0.7623
October	12.78	0.5588
November	8.406	0.4041
December	7.799	0.3772
mean	16.72	0.6374
mean*8784.0 h	146846.8	5598.5
min	7.66	0.3706
max	33.23	1.053

Zone 9

	Variables	
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PMV, Predicted Mean Vote, at occupant 1
January	6.971	0.299
February	7.28	0.3176
March	10.63	0.4912
April	16.26	0.6792
May	28.37	0.9859
June	31.1	1.047
July	38.21	1.2
August	35.51	1.142
September	24.98	0.9167
October	15.62	0.6584
November	8.709	0.3986
December	6.679	0.2598
mean	19.25	0.7011
mean*8784.0 h	169066.6	6158.4
min	6.679	0.2598
max	38.21	1.2

Zone 10

	Variables					
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PPD, Predicted Percentage of Dissatisfied, at occupant 2, %	PPD, Predicted Percentage of Dissatisfied, at occupant 3, %	PMV, Predicted Mean Vote, at occupant 1	PMV, Predicted Mean Vote, at occupant 2	PMV, Predicted Mean Vote, at occupant 3
January	4.37	5.302	4.768	-0.01555	-0.02316	-0.01569
February	4.456	5.395	4.853	0.01585	0.01719	0.02224
March	6.221	7.62	6.913	0.2602	0.3216	0.2937
April	9.503	11.45	10.48	0.4358	0.5276	0.4809
May	17.89	21.52	19.9	0.6855	0.8287	0.7583
June	20.78	25.38	23.09	0.7552	0.9191	0.8333
July	29.91	36.45	33.18	0.975	1.187	1.076
August	25.68	31.94	28.82	0.8736	1.08	0.9719
September	14.21	16.76	15.58	0.5974	0.71	0.654
October	9.409	11.29	10.31	0.4275	0.5137	0.4687
November	5.134	6.292	5.649	0.1292	0.1546	0.1437
December	4.898	5.794	5.28	-0.05096	-0.06956	-0.05619
mean	12.75	15.49	14.12	0.4257	0.516	0.4711
mean*8784.0 h	112035.6	136094.5	124059.3	3739.4	4532.5	4138.0
min	4.37	5.302	4.768	-0.05096	-0.06956	-0.05619
max	29.91	36.45	33.18	0.975	1.187	1.076

Zone 11

	Variables			
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PPD, Predicted Percentage of Dissatisfied, at occupant 2, %	PMV, Predicted Mean Vote, at occupant 1	PMV, Predicted Mean Vote, at occupant 2
January	4.889	4.905	-0.1391	-0.1403
February	5.024	5.1	-0.1302	-0.1365
March	5.11	5.0	0.1431	0.1281
April	8.618	8.245	0.3859	0.3693
May	17.99	17.01	0.6868	0.6614
June	21.39	20.71	0.7731	0.7573
July	30.31	29.28	0.9863	0.9647
August	25.82	24.81	0.8798	0.8579
September	13.62	13.23	0.5838	0.5713
October	8.337	8.178	0.3678	0.3592
November	4.784	4.79	0.01288	0.01108
December	5.667	5.687	-0.18	-0.1817
mean	12.68	12.29	0.3661	0.3537
mean*8784.0 h	111354.0	107953.4	3215.8	3106.7
min	4.784	4.79	-0.18	-0.1817
max	30.31	29.28	0.9863	0.9647

Zone 12

	Variables	
	PPD, Predicted Percentage of Dissatisfied, at occupant 1, %	PMV, Predicted Mean Vote, at occupant 1
January	5.658	-0.2362
February	5.698	-0.2272
March	4.275	0.03316
April	6.722	0.2795
May	15.53	0.592
June	18.4	0.671
July	26.07	0.8585
August	22.02	0.758
September	12.1	0.5133
October	6.974	0.2742
November	4.701	-0.09145
December	6.807	-0.2739
mean	11.29	0.2644
mean*8784.0 h	99128.6	2322.5
min	4.275	-0.2739
max	26.07	0.8585